Madras Manual of Hygiene

1880

PREFACE.

THIS edition has been carefully revised and certain changes have been made which will, it is hoped, add to the usefulness of the Manual. Twenty-six paragraphs have been added to the first nine chapters; and a few paragraphs on Village Hygiene to Chapter X. Chapter XI on Epidemics and Epizootics and Chapter XII on Sanitary Law are new. Appendices on Famine, on Famine Foods, and on Quarantine have been added; the Dietaries Appendix has been condensed and otherwise improved: while the Appendices relating to Madras Waters, Soils, and Climates have been omitted. That of Statistics has been brought down to date as far as possible.

I have to thank my friends Surgeons-Major Cornish, Bidie, and Macrae, and Surgeon W. Hamilton for the kind assistance they have given me.

February, 1880. H. K.

CONTENTS.

CHAPTER I.

INTRODUCTION.

CHAPTER II.

AIR.

CHAPTER III.

WATER.

CHAPTER IV.

FOOD.

CHAPTER V.

SOILS.

CHAPTER VI.

DWELLINGS.

CHAPTER VII.

CLOTHING.

CHAPTER VIII.

EXERCISE.

CHAPTER IX.

CLIMATE AND METEOROLOGY.

CHAPTER X.

MILITARY AND VILLAGE HYGIENE.

CHAPTER XI.

EPIDEMICS AND EPIZOOTICS.

CHAPTER XII.

SANITARY LAW.

CHAPTER XIII.

STATISTICS.

APPENDIX I.

FAMINE.

APPENDIX II.

DIETARIES.

APPENDIX III.

APPENDIX IV.

MEDICAL INSPECTION AND QUARANTINE OF SHIPPING.

APPENDIX V.

MADRAS STATISTICS.

APPENDIX VI.

THE MADRAS MANUAL OF HYGIENE.

CHAPTER I.

INTRODUCTION.

HYGIENE is the Science of Health. Its subject is everything capable of affecting the sanitary condition of human beings or of the lower animals dependent on or connected with Man. Its principal object is the discovery of the laws on which depends the efficient performance of the physical and mental functions of Man. The practical application of these laws to the prolongation of life, the preservation of health and the prevention of disease constitutes the Art of Preventive Medicine.

2. The most important subjects requiring investigation in relation to human health are: the AIR we breathe; the CLIMATE in which we live; the WATER we drink or use for other purposes; the FOOD with which we maintain our minds and bodies; the SOIL on which we tread and build; the DWELLINGS we inhabit; the CLOTHING we wear; and the EXERTION, physical and mental, which we undergo. These relate principally to the preservation of health. With a view to the prevention of disease the conditions essential or favorable to the generation, spread and decline of special maladies must be studied, more particularly in the case of EPIDEMICS. It is obviously often impossible to say where preservation ends and prevention begins, but the distinction is on the whole convenient. Preservation is more general in its aims and efforts; prevention more special.

3. The prevention and extirpation of EPIZOOTICS* form a subject of considerable importance, both primarily,

* Diseases prevailing extensively amongst species of the lower animals at any particular time.

and secondarily in connexion with Food. The study of EPIPHYTICS* also, of their causes and remedies, in relation to Hygiene, is deserving of more attention than it has yet received. ENDEMICS† are dependent upon Soil, Water, Climate and other more general heads of inquiry.

4. Ignorance, apathy and indisposition to change, no less (but scarcely more) prevalent in this country than in the West, render necessary the pressure of LAWS, to enforce attention and obedience to established sanitary principles. Hitherto sanitary legislation in India has been tentative and more than cautious. How closely it may follow in the footsteps of Western experience, without exciting impatience and irritation to such a degree as would outweigh the benefits proposed, is a subject which demands most careful inquiry into the effects of legislative measures now in force upon the opinions, feelings and prejudices of the population. The chief use of sanitary STATISTICS in this country at present is first to ascertain and then to demonstrate that sanitary measures have produced definite improvement in the condition of the people. By this means prejudices will best be overcome, and the way prepared for further beneficial legislation.

* Diseases widely affecting one or more species of the vegetable kingdom. The word is used with a different meaning in technical Botany.

† Diseases generally prevailing in a particular locality.

CHAPTER II.

AIR.

5. Atmospheric **air** consists of a mixture of oxygen and nitrogen, with small quantities of carbonic acid and aqueous vapor, and traces of nitric acid, ammonia, and marsh gas or some other combination of carbon and hydrogen. Air is impure when it contains excess of any of its ordinary components or any substance besides them.

6. The normal proportion of **oxygen** may be taken as 20·96 volumes in 100. In pure air over mountains it rises to 20·98; in towns it falls to 20·90 or even lower.*

7. **Ozone** is a modified and more active form of oxygen. It is generally present in the atmosphere, more abundantly at night than by day, and is believed to be beneficial, unless when in excess, in which case irritation of the bronchial passages results. It is absent from the air of ill-ventilated sick-rooms, and at a minimum during cholera epidemics. It is produced by the passage of electrical discharges through air, and by other means. Its amount is estimated by the degree of blueness given in a definite time to test-papers prepared with a mixture of potassium iodide and starch. Other causes, however, are capable of producing the same coloration, and a quantitative test for ozone which can be depended upon has yet to be discovered.† It is converted to ordinary oxygen by heat, slowly at 100° C., instantaneously at 300° C.

* Regnault found the mean of 100 Paris samples to be 20·96, the maximum being 20·999, the minimum 20·913. The mean maximum of 195 samples from various sources examined by him was 20·988. The mean minimum 20·949. The variations are almost invariably confined to the second or third decimal place.

† Other tests are the browning of test-papers dipped in the manganese sulphate, and the whitening of paper stained by lead sulphide.

8. Ozone is an allotropic modification of oxygen, and its molecule is supposed to contain three atoms, while that of ordinary oxygen contains two. Its density is one-twelfth greater, its power of oxidation superior. All the processes of Nature which develope electricity by friction, chemical action or otherwise, generate ozone Its presence in considerable quantity is attended with a peculiar pungent odor, as when the electric spark is passed several times in succession through air, and from this fact its name is derived.

9. The oxidation of the essential oils of odoriferous plants is also supposed to cause the evolution of ozone. In most cases the development takes place only under the influence of sun-light, but it also occurs in the dark. The cultivation of aromatic and flowering plants about unhealthy places is, therefore, indicated.

10. **Nitrogen** is not directly poisonous, and slight excess of it, which may occasionally and temporarily exist, is not injurious. The average proportion may be stated as 79 volumes per 100.

11. **Carbonic acid** varies in amount, in pure air, from 0·2 to 0·5 volume in a thousand. The average is taken at 0·4 and the quantity is excessive when it exceeds 0·5. The proportion increases as we ascend from sea-level to a height of 11,000 feet, diminishing above this elevation; it is less over sea than over land, and is greater in sea-air by day than by night, the difference being from 0·054 to 0·033 per cent. It is diminished by heavy rain, which washes it out of the atmosphere. The ordinary *causes* of excess of carbonic acid in the atmosphere are the respiration of animals, the exhalation from their skins, combustion and putrefaction. It is, therefore, more abundant in densely populated districts. The mean of 18 determinations by Dr. A. Smith of carbonic acid in the air of close places in London was 1·288 volume per 1,000, the maximum 3·20. In a crowded school-room Pettenkofer found 7·23 per 1,000.

12. Respired air contains 40 volumes of carbonic acid in a thousand, an adult man at ordinary labor giving out from his lungs from 12 to 16 cubic feet in 24 hours. An undetermined quantity is exhaled from the skin of living animals. A given volume of coal-gas produces, when burnt, about twice its bulk of carbonic acid. The combustion of a pound of oil generates nearly as much as 10 cubic feet of gas. A pound of dried wood requires 120 cubic feet of air for complete combustion, the principal product being carbonic acid; and a pound of coal requires

twice as much. Putrefaction is chiefly the slow oxidation of organic matters, by which, amongst other changes, carbon is converted into carbonic acid. This gas constitutes 16 per cent. of the emanations from sewage, and sometimes 2 or 3 per cent. of sewer-air. The atmosphere of burial-grounds has been found to contain from 0·7 to 0·9 volume per thousand, and that of marshes from 0·6 to 0·8 or more.

13. The **effects** of breathing air containing excess of carbonic acid vary, not only with the quantity present, but also with individual peculiarities. In some persons 15 to 20 volumes per thousand produce severe headache, while others can inhale with impunity air containing a much larger proportion. The fatal dose ranges between 50 and 100 volumes per thousand. It is probable that a much smaller amount than 15 per thousand produces a degree of discomfort indicative of incipient intoxication.

14. It is difficult to ascertain the effect of excess of carbonic acid alone. In respired air organic matters and other deleterious gases are present also, and answerable for much of the injurious result of inhalation. In manufactories of aërated waters air containing 2 volumes per thousand of carbonic acid is breathed without mischief; but respired air containing one volume produces perceptible ill-effects, and if from 1·5 to 3 be present, headache and vertigo result. It has been conjectured that inhalation of air containing excess of carbonic acid is a common source of phthisis, but the facts which appear to support this view relate to air vitiated by all the products of respiration, not by carbonic acid only.

15. The ill-effects of the latter are only partly due to direct intoxication. Its presence in excess diminishes the supply of oxygen to the blood, and impedes effective elimination of carbonic acid from the lungs.

16. The **estimation** of the amount of carbonic acid present in the atmosphere is effected by means of a solution of baryta of known strength. A certain quantity of the solution being brought into contact with a known volume of the air to be examined, the carbonic acid of the latter forms a carbonate with the metal, diminishing proportionately the alkalinity of the solution. The loss of alkalinity is, therefore, a measure of the carbonic acid present.

17. Take a vessel of known capacity, from 5 to 15 litres; dry, and fill it by means of a bellows with the air to be examined; pour in 45 c.c. of baryta-water, (1 litre of which contains 7·000 grms. crystallized barium hydrate*), and close the month with an india-rubber cap. Agitate the vessel, so that its whole internal surface may be wetted by the solution, and let it stand for half an hour. Then transfer the solution to another vessel and allow the carbonate to subside. Take out 30 c. c. of the solution and ascertain its alkalinity, comparison of which with that of the original solution will show the amount of barium carbonate formed, and therefore the amount of carbonic acid present in the volume of air which the vessel contained, *i.e.*, the capacity of the vessel *minus* 45 c. c. occupied by the solution. A simple proportion gives the volumes per thousand.

18. To estimate the alkalinity dissolve 2·8636 grms. of crystallized oxalic acid in a litre of distilled water. 1 c. c. of this solution will correspond to 0·001 grm. of carbon dioxide.† Neutralize exactly 30 c. c. of the original baryta-water with the oxalic solution, ascertaining neutralization with turmeric-paper. As each c. c. of the baryta-water corresponds nearly to 1 milligram of CO_2, about 30 c. c. of acid solution will be required. After the baryta has combined with the carbonic acid and the carbonate has subsided, neutralize 30 c. c. of the supernatant baryta-solution. Subtract the result of the second operation from that of the first; the difference in cubic centimeters, multiplied by 1·5 (because 45 c. c., not 30 c. c., were put into the vessel), gives the number of milligrams of carbon dioxide which have combined with the baryta. This number $\times$ 0·505817 ‡ = number of c. c. of carbon dioxide at standard temperature and pressure. Temperature and pressure at time of filing the vessel with air must be noted, and the volume reduced to standard temperature§ and pressure.‖

19. Another method is to pass the given volume of air, freed by means of strong sulphuric acid from aqueous

* Each c. c. of this solution of $BaH_2O_28 (H_2O)$ corresponds to 1 mgrm. of CO_2, nearly. 44 : 315 : : 0·001 : 0·007159.

† The molecular weight of crystallized oxalic acid (H_2,C_2O_4, $2H_2O$) is 126; of CO_2 44. 126 : 44 : : 0·002836 grm. (contained in 1 c. c. of acid solution) to 0·001 grm.

‡ A litre of CO_2 at 0° C. and 760 mm. weighs 1·977 grm. Therefore each milligram occupies 0·505817 c. c.

§ Standard temperature is 0°. The following is the formula for the correction of observed volume for temperature—$v' = \frac{v}{1+0{\cdot}003665.\,t}$; v' being corrected, and v observed volume, t observed temperature, and 0·003665, the coefficient of expansion for each degree.

‖ The following proportion gives the correction for pressure—standard pressure (760 millimeters) : observed pressure : : observed volume : corrected volume.

vapor, through a known weight of solution of potash. The carbonic acid forms potassium carbonate. The increase of weight divided by 1·977 = volume of carbonic acid in given volume of air.*

20. The quantity of **aqueous vapor** varies from 10 per cent. of the amount necessary for complete saturation upwards. Air absorbs moisture from water with which it is in contact; respired air is saturated with watery vapor, and the lungs and skin of an adult exhale from 25 to 40 ounces of water in 24 hours; water is one of the products of the combustion of ordinary fuel. The hygienic effect of dryness or humidity upon health, and the proportion of atmospheric moisture most favorable to health are not known. The latter has been supposed to be from 65 to 75 per cent., but many healthy climates exhibit a much higher degree of humidity than this. The amount present may be ascertained by drawing a known volume of air through a tube containing pieces of pumice-stone moistened with strong sulphuric acid, which deprives the air of its water, and weighing the tube before and after the process. The increase of weight represents the quantity of water present in the known volume of air. Hygrometers or comparison of two thermometers, one with a wet bulb and the other under ordinary conditions, enable us, with the aid of tables, to determine the amount of aqueous vapor in the atmosphere at any particular time. The processes will be explained hereafter.

21. Traces of **nitric acid** are always present in air, and more distinctly after heavy rain and electrical disturbance. It has no influence upon health. It may be detected and estimated by applying to rain-water, or to distilled water, through which a given volume of air has passed, the appropriate tests; which will be described in the Chapter on Water.

22. Traces of **ammonia** also are present in pure air, and the quantity is increased after heavy rain. When moist animal matters, containing both nitrogen and hydrogen, decompose, ammonia is formed. Nascent hydrogen, derived from water resolved by any means into its constituents, unites with atmospheric nitrogen to form ammonia.

* The increase of weight is CO_2 a litre of which weighs 1·977 grm.

It is one of the products of the combustion of coal. It never occurs in sufficient quantity to be directly hurtful, except, perhaps, as an irritant of the conjunctiva; but its presence in abnormal amount indicates the existence of danger from other substances directly noxious. Sewer-air and the liquid which collects on sewer walls are often alkaline from ammonia. It is present in excess in the atmosphere of burial-grounds, and occasionally in that of marshy places. Its presence may be detected by the brownish color which it gives to log-wood test-paper.* Its quantity may be ascertained by means of Nessler's Test applied to distilled water, (which had been ascertained to be itself free from ammonia) with which the sample of air has been washed.†

23. IMPURITIES of the air are either solid or aëriform, the former suspended, the latter diffused, in it. **Inorganic** solids are derived from the soil or sea, from buildings, and from the materials with which certain employments are concerned. Minute particles of flint, clay, carbonate and phosphate of calcium, ferric oxide, of carbon, tarry matters and sulphur, (arising from imperfect combustion of coal or wood), are raised from the surface and kept suspended in the atmosphere. Chloride of sodium, derived from the sea or the soil, is almost invariably present. The air of coal mines, of potters' workshops, of rooms where steel instruments are ground, of stone-cutters' yards and of other places where the nature of the work involves the dispersion of fragments of mineral matter, becomes more or less impregnated with inorganic impurities.

24. **Organic** suspended matters are more numerous, more varied and more dangerous. Winds raise dust from the soil which is found to contain from 36 to 46 per cent. of organic matter. Evaporation from the surface of water, especially in marshy places, raises minute organized particles into the atmosphere. Thus the remains of dead animals and vegetables, minute living organisms, as vibrios,

* Evaporate some tincture of log-wood to dryness; dissolve the residue in ether, and dip strips of filter-paper in the solution.

† A kilogram of air from Chelsea contained 0·035 mgrm. of free ammonia; from the atmosphere over dust-heaps 0·26 mgrm. and 0·32 mgrm.—the same as bad well-water. A kilogram of London water was found to contain 0·01 mgrm.

bacteria and monads or mucedines, torulæ and mycoderms, germs of infusoria or of higher forms, pollen, spores and seeds float in air comparatively pure. In sewer-air meat and milk are tainted rapidly, owing to the abundant presence of low forms of animal and vegetable life. Starch-cells, hair, wool, cotton-fibres are also present, especially in dwellings, and more abundantly where manufactures of bread, clothing, &c., are carried on. Pus-cells and epithelium, excretions, cutaneous, pulmonary, urinary or fæcal, dried and pulverized, will abound in the atmosphere of dirty and ill-ventilated houses, and in ill-kept hospitals more particularly.

25. Suspended atmospheric impurities **act injuriously** upon health in several ways. The pus-cells of ophthalmia may float from affected to healthy eyes and communicate the disease. Certain parasitic skin-diseases, erysipelas and hospital gangrene, perhaps metria, may also be propagated by germs or by direct local action of organic poisons so conveyed. The poison of typhoid may thus reach the intestinal mucous membrane and act. The lungs or nasal mucous membrane may be mechanically irritated by particles of mineral matters, or by fibres of cotton or wool, and bronchitis and other pulmonary affections or coryza ensue. The blood may be poisoned by air inhaled containing the specific virus of cholera, typhus, typhoid, paludal fevers, dysentery, variola, scarlatina or measles. Phthisis possibly, the pleuro-pneumonia of cattle certainly, may be propagated by sputa. Whether diseases are propagated by living germs or by dead animal poisons the morbific cause may enter the blood through the lungs.* Again, suspended impurities, except the very lightest, are not likely to reach the lungs, but will lodge on the mucous membrane of the nose, the fauces or the mouth, and pass thence by deglutition into the stomach and intestines. Here they may set up dyspepsia, &c., by local irritation, or they may propagate specific diseases through the intestinal tract. When maladies, not pulmonary, are due to inhalation of foreign matters suspended in the air, these more probably act by being swallowed than by entering the blood through

* The condition of the organic substances which cause specific diseases is unknown. They may act directly as thrown off from a diseased surface, or after undergoing putrefactive changes.

the lungs. This is true not only of diseases due to organic poisons, but also of the saturnine, mercurial, cuprine and arsenical intoxications, to which painters and plumbers and workmen employed with mercury, copper and arsenic are liable.

26. Air containing much organic matter blackens sulphuric acid through which it may be drawn, and reddens a solution of silver nitrate. The **nature** of suspended impurities is ascertained by the microscope. For collecting them two methods are available. A vessel of known capacity is filled with water which is allowed to run out below while an aperture above, to which a funnel with its neck drawn into a fine tube is fitted, admits the air. Below the opening of the funnel a slip of glass moistened with glycerine is fixed, which catches the solids suspended in the air as it enters. Or a known volume of air may be drawn through distilled water and the sediment collected.

27. The **remedies** for this form of impurity are heat, corrosive disinfectants, filtration and ventilation. Cotton wool intercepts all foreign substances suspended in the air drawn through it, and respirators made of this material are capable of protecting efficiently persons engaged in employments which disperse solid particles in the atmosphere, and all who are liable to diseases dependent upon the inhalation of solid morbific material. The nasal passages, to a certain extent, filter the air which passes through them, and the unnatural habit of breathing through the mouth should, therefore, be avoided. Ventilation will be considered hereafter. It is only necessary to remark in this place that *topical* ventilation—bringing a strong stream of air to bear upon the immediate neighbourhood of tool-grinding and similar machines—has been attended with results most favorable to the health of the workmen.

28. Natural processes tend to keep down the amount of suspended impurity. The heavier substances spontaneously subside. Rain washes others to the earth or carries them down in solution. Part of the organic matter is gradually oxidized into carbonic acid and water or other aëriform substances.

29. The **volatile** impurities of air are: organic vapors, carbon monoxide, marsh-gas, sulphuretted hydrogen,

sulphide of ammonium, sulphurous and sulphuric acids, carbon disulphide, hydrochloric and nitrous acids, and phosphide of hydrogen.

30. Of these the most important, because the most injurious to health, are **organic vapors** of unknown composition, and probably of many different kinds. Some properties of these substances render it even doubtful whether they are aëriform or solid. They do not appear to be diffused like true vapors, but seem to float in clouds in foul atmospheres, and the offensive odor which is characteristic of them is not equally prevalent in all parts of a room in which they have been generated. They resist oxidation longer than other impurities, and therefore require freer and more prolonged ventilation than they. It is probable that they are either in combination with, or in solution in, aqueous vapor; as substances which most readily absorb water, or condense it upon their surface, are found to collect most abundantly the organic products of respiration. The color of the absorbent material is said to influence the amount of organic matter absorbed; black objects collecting most, then blue and yellow, white least.

31. The decomposition of organized structures gives rise to organic vapor; but the most important source is the exhalations, cutaneous and respiratory, of men and other animals. Putrid organic vapor exists in the air of sewers and of burial-grounds, but that which accumulates in ill-ventilated and crowded buildings is more abundant and more noxious. The quantity of organic matter given off from the lungs and skin of an adult man is considerable but has not been determined,* the organic products of the skin being suspended, those of the lungs vaporous.† In hospitals and rooms where sick or wounded persons lie organic exhalations are still more abundant. To the

* Dr. Angus Smith estimates the animal matter in *respired* air at 3 volumes per mille, in the form of putrescible albuminoid substance.

† The following numbers represent, with reference to the quantity of "organic matters" present, the comparative purity of different atmospheres, as determined by Dr. Angus Smith :—pure air on high ground 176 and 209; in a bed-room 56 and 64; inside a house 16; in a closely packed railway carriage 8; in a house sewer 8; in a cesspool 0·062.

ordinary products of respiration increased cutaneous exhalations are added, and effluvia from various excretions.

32. It is not possible to isolate the **effects** of inhalation of organic vapor from the other consequences of breathing air contaminated with sewage emanations or with the products of respiration; the general effects will be mentioned hereafter. Of the complex poison of respired air the organic vapor is the most active ingredient, and those symptoms which cannot be traced to deficiency of oxygen are chiefly due to it. In cases where death has resulted from overcrowding, without absolute exclusion of fresh supplies of air, organic vapor has probably been the cause.

33. The peculiar fœtid odor of organic vapor exhaled from lungs and skin enables its presence in occupied rooms to be **detected.** Barrack-rooms, jail-wards, school-rooms and rooms where crowded meetings have been held are likely to present this conclusive evidence of insufficient ventilation. Few hospitals are free from it (though all may be and ought to be), the productive causes being more active in them than in other buildings. The odor is too often perceptible, in barrack-rooms for instance, by day; but suspected quarters should be visited in the early mornings after the full number of inhabitants has occupied them for some hours. It is to be remembered that the inmates themselves are unconscious of the fœtor; that it is more perceptible in proportion to the purity of the atmosphere from which the inquirer has passed in; that breathing foul air impairs, and gradually destroys for the time, the perception of its foulness, and that this sensibility is not immediately restored on return to purer air; and that ability to perceive lower degrees of this peculiar taint is capable of cultivation by practice.

34. Organic vapor of this kind being generated simultaneously with carbonic acid, the quantity of the latter arising from respiration affords a means of roughly **estimating** the degree of contamination by the former. Much carbonic acid implies the presence of much organic vapor. When the atmosphere of a room, previously pure, becomes gradually vitiated by respiration, the organic fœtor is easily perceptible when the carbonic acid rises to 0·7 volume per mille, and very strong when the proportion amounts to 1·0.

35. More accurate means of determining the quantity of organic matter present in the air are supplied by the

potassium permanganate test and the process of conversion of nitrogenous impurity into ammonia—a known volume of air being drawn through distilled water. Both these methods necessarily apply to the whole of the organic matters, not solely to that which is supposed to be in the aëriform condition; but the latter process more especially affords the best quantitative test of atmospheric impurity. They will be described in the Chapter on Water.

36. **Carbon monoxide** or carbonous oxide is one of the products of combustion of coal and wood. It is capable of passing through the heated walls of iron stoves, less freely through wrought than through cast iron, and its passage is impeded if the stove be lined with fire-clay. Air containing less than 5 volumes per mille, breathed by a small animal, produces symptoms of poisoning, and if more than 10 be present it proves rapidly fatal. It enters the blood through the lungs, displacing an equal volume of oxygen, and can only be removed gradually after oxidation and conversion into carbonic acid. The red globules of the blood become incapable of their function of carrying oxygen to the tissues. Consciousness is lost, reflex action destroyed, atony of the vessels produced, diminishing vascular pressure, causing retardation of the circulation and finally paralysis of the heart. The inhalation of this gas is found to produce very rapid parenchymatous degeneration of all the muscles and of the solid abdominal viscera.

37. **Marsh-gas** or light carburetted hydrogen is a product of the decomposition of organic matter, and constitutes 73 per cent. of the gases emanating from London sewage. It is generally found in the air over marshes, arising from the putrefaction of vegetable substances. It is a principal constituent of coal-gas. In small quantities it does not appear to produce any ill-effect, and air containing as much as 200 or even 300 volumes per mille may be breathed for some time with apparent impunity. In larger proportion it produces headache, vomiting, convulsions, stertor with dilatation of the pupil and death. Habitually breathed even in small quantities it can scarcely fail to be injurious.

38. **Sulphuretted hydrogen** is a result of the putrefaction of organized substances containing sulphur; and

also of the action of organic matter on sulphates dissolved in water, which are converted into sulphides, these being decomposed by animal or vegetable acids: it is also an occasional product of combustion of coal and wood. Hence it constitutes sometimes 2 or 3 per cent. of sewage emanations and may amount to 3 per cent. or more of sewer atmosphere; it is found in the air of marshy places, especially of salt-marshes, as those of Singapore; it is present in the foul holds of ships,* and in the smoke of brick-kilns. It is invariably present in coal-gas and rarely in less proportion than 0·3 per cent.

39. There are great uncertainty and conflict of opinion as to the **effects** of this gas upon the system when inhaled. Breathed undiluted it destroys life at once. Injected in solution directly into the blood it produces the same train of symptoms as putrid animal fluids—profuse diarrhœa, sometimes resembling cholera in the loss of animal heat and general collapse, congestion of the lungs and abdominal viscera, irritation of the spinal cord and opisthotonos. In the smaller doses of inhalation, however, the lower animals, as dogs and horses, suffer from diarrhœa with prostration of strength when the atmosphere contains from 1·25 to 4 volumes of this gas per 1,000: while men have breathed as much as 29 per mille, for a short time, with impunity. In ordinary cases, where inhalation has been continuous but the proportion small, effects have been contradictory: some persons suffering, others remaining apparently unaffected. The intensity of malarious intoxication in some Italian marshes has been attributed to the admixture of sulphuretted hydrogen in the air; while others have supposed it to have a neutralizing effect upon malaria. The symptoms of chronic poisoning seem to be weakness, anorexia and anæmia. In acute cases the symptoms are sometimes narcotic, sometimes convulsive.

40. The characteristic odor of this offensive gas renders its presence, even in small quantities, **perceptible.** It blackens white paint prepared from lead carbonate, and a slip of white filter-paper dipped in a solution of a lead salt, (as the acetate), is blackened by a quantity too small to

---

* Grain saturated with sea-water becomes highly offensive from this cause chiefly: and in a recent case a man employed in clearing a wrecked vessel of putrid rice died poisoned or asphyxiated.

be detected by the smell, the black lead sulphide being formed. The method of quantitative determination will be given hereafter.

41. **Sulphide of ammonium** is derived from the same sources as sulphuretted hydrogen. In large doses it asphyxiates when inhaled; in smaller it produces vomiting without purging, quickness of pulse, heat of skin, followed by collapse. Injected in solution into the blood, its effects resemble those of sulphuretted hydrogen. Its presence is detected by the sodium nitro-prusside which, with this (and the other alkaline sulphides), gives a brilliant purple color.

42. **Sulphurous acid, sulphuric acid,** and **carbon disulphide** are products of the combustion of coal and, in a less degree, of wood. Imperfectly purified coal-gas generates, when burnt, the former two, but none of them is of any importance as regards health, their quantity being insignificant. Inhalation of sulphurous acid undiluted is fatal; in small amounts it produces lacrymation and sneezing; in considerable quantity, bronchitis and ultimately anæmia.

43. **Nitrous acid** is formed by the oxidation of nitrogenious substances and traces of it are frequently present. **Phosphuretted hydrogen** arises from the decomposition of organic animal and vegetable matter containing phosphorus. It is found occasionally over marshes and in burying-grounds.

44. The **effects** of breathing an impure atmosphere are to be looked for not merely in the production of definite, still less of specific, ailments, but also in an impaired condition of general health, shown by increased liability to, and greater severity of, diseases, protracted convalescence, shortened duration of life, higher death-rate, especially of children. None of the impurities above described occurs singly, and different combinations of them are found under different circumstances, producing various effects. These must be briefly considered before entering upon the subject of the means by which atmospheric impurity is mitigated or removed.

45. The air of **crowded rooms** or dwellings contains excess of aqueous vapor and of carbonic acid, as well as the fœtid and exceedingly poisonous organic vapor exhaled from lungs and skin. The effects of breathing such an

atmosphere are well marked. A few hours suffice to produce febrile symptoms, hot skin, rapid pulse, furred tongue, anorexia, thirst, &c., and these effects persist for one or more days afterwards. If the intoxication be still more acute, as when the proportion of space to number of living beings is excessively low, asphyxia from deficiency of oxygen and direct poisoning from organic exhalations combine to destroy rapidly the life of the most susceptible, while the survivors suffer for some days subsequently from symptoms similar to those just described; and the impairment of the vital powers is sometimes evinced by boils. Living habitually in an atmosphere tainted in a lower degree with the products of respiration exercises a most injurious influence upon the general health; often aggravated by want of exercise as in the case of tailors, sempstresses, school-children &c., by the presence of dust of various kinds in many manufactures, or by idleness and ennui in the case of the soldier. Paleness, with loss of appetite, strength and spirits, shows deterioration of health and consequent inability to resist epidemic or infectious disease. The proportion of phthisis and of pulmonary diseases is higher amongst persons exposed to these unfavorable conditions and the diminution of such affections among soldiers and sailors by improved ventilation of barracks and ships has been marked. Cows, horses &c. suffer like human beings, and it is well known that the monkeys in the London collection died in large numbers of tubercular phthisis, so long as the arrangement of their quarters was such as to prevent the escape (except by diffusion) of the products of respiration.

46. The air of rooms or buildings devoted to the sick necessarily contains additional impurities. The proportion of organic matter, both suspended and vaporous, is much increased; producing, unless corrected, not only general impairment of vital power, shown by intensified disease and retarded convalescence, but also specific maladies of which the generating causes accumulate if not removed. Under such circumstances erysipelas and hospital gangrene may be developed and the communication of other infectious diseases favored.

47. The products of **combustion** rarely accumulate. Breathing the air of close rooms where lamps, especially gas-lamps, are burning, sometimes causes headache and a feeling of oppression, owing to the formation of the oxides

of carbon; and much sulphurous acid arising from the combustion of coal-gas may produce some bronchial irritation. Minute quantities of this acid, as well as particles of carbon and tarry matters, may act rather beneficially than otherwise. Indirectly combustion may be injurious to persons chilled by passing from a heated room to the colder atmosphere without.

48. The decomposition of animal matter yielding carbonic acid, marsh-gas, nitrogen in large quantity, (sewage emanations sometimes containing 10 per cent.), sulphuretted and phosphuretted hydrogen, ammonia and acetic acid; and that of vegetable matter, carbonic acid, nitrogen and acetic acid; **sewer-air** generally contains some ingredients which are asphyxiating and others which are directly poisonous. The opening of cesspools has thus proved fatal to workmen. Ophthalmia, bilious diarrhœa, and colic have been known to prevail amongst persons employed about sewers. The habitual inhalation of air polluted by communication with sewers produces headache, nausea, diarrhœa, general malaise; and, if continued long, great impairment of health and a state of anæmia. Sometimes brief febrile attacks, characterized by severe headache and derangement of digestive organs, have been observed. Diarrhœa may arise from the emanations from fæcal matters in sewers, especially if the poisonous effects are concentrated by high temperature and drought, which may also assist by rendering the water-supply impure. The connexion of enteric fever with sewer-air is still obscure. Emanations from sewers containing the stools of typhoid patients will undoubtedly produce the disease in persons unprotected by a previous attack. Imperfect sewerage favors the spread of typhoid, improved sewerage has been followed by disappearance of the fever. On the other hand fæcal accumulations may exist for years, and their emanations pollute the air without the production of this specific disease. It seems probable, therefore, that, as a general rule, sewer-air must contain the specific poison of enteric fever in order to generate the disease; while the possibility of *de novo* origination, through the concurrence of complex and unknown conditions, cannot be denied. Other diseases, as erysipelas, hospital gangrene, the exanthemata, venereal affections, puerperal fever &c., have their severity aggravated in an atmosphere tainted by sewer emanations.

49. The effect, general and special, upon health, of **fæcal matters** accumulated and concentrated in sewers is pernicious, if they are permitted to contaminate the air we breathe; but, when they are scattered upon the surface of the ground, they are comparatively harmless, however disagreeable. Their emanations are immediately and copiously diluted with ordinary air. Collected in heaps they are nearly as hurtful as in open sewers. Mixed with earth they, in most cases, lose all dangerous properties; though specific poisons, as that of enteric fever, may not be thus destroyed and may propagate disease. Emanations from streams into which sewers discharge excrementary matters will generally be diluted to harmlessness.

50. Residence in or in the neighbourhood of **grave-yards** is necessarily unwholesome. Although the impure atmosphere may cause no definite disease, it impairs health and diminishes power of resistance to morbific causes. The polluted water of such localities contributes to this result. The decomposition of unburied animals, as in dissecting-rooms on the small scale and battle-fields on the large, sometimes appears to produce bowel-complaints and can scarcely fail to render the air unwholesome always, though satisfactory evidence is wanting. Attendance at funerals appears to have been sometimes injurious to the health.

51 The air of **marshes**, and of other places not apparently wet, where organic vegetable matter is undergoing decomposition, produces intermittent fevers and congestion of the spleen with impairment of nutrition and shortening of the mean duration of life. Malarious dysentery sometimes results. These effects, however, are probably due as much to the water of such localities as to the air.

52. Air is **purified** by rain which carries dissolved and suspended matters to earth; by winds and currents dispersing and diluting foreign substances; by the vegetable kingdom which, under the influence of light, decomposes carbon dioxide, retaining carbon for its own structures and giving out oxygen; by oxidation of putrescent organic matter; by diffusion of aëriform bodies; by deodorants and disinfectants; and by ventilation.

53. **Diffusion** is the intermixture of aëriform bodies which do not act chemically on each other and which are

either directly in communication or separated by a porous medium. Two gases or vapors thus intermixed can be separated only by chemical action or condensation of one of them. The rapidity with which diffusion takes place varies with the difference of densities of the diffusing bodies ; the greater this difference, the more active is the process of intermixture.

54. The diffusiveness or *diffusion-volume* of a gas varies inversely as the square-root of the density ; therefore, the time of diffusion (which is inversely as the volume diffused) varies directly as the square-root of the density.* As all aëriform bodies may be taken to expand equally under the influence of equal increments of heat, their relative densities are constant, and, therefore, their *relative* velocity of diffusion is unaffected by changes of temperature. The *total* rate of diffusion of equal volumes is increased by increase of temperature, because thereby the densities are diminished ; but the rate of diffusion does not increase so rapidly as the expansion by heat. Whence it follows that a given weight of any gas or vapor is diffused more rapidly at a low than at a high temperature.

55. **Deodorants** are substances which destroy offensive odors or mask them by others, agreeable or less disagreeable. There is no necessary connexion between stinks and injurious atmospheric impurity ; some offensive gases and vapors (as sulphuretted hydrogen, ammonium sulphide and organic respiratory vapor) being deleterious, while others, also poisonous, (as the carbon oxides and malaria) are not perceptible by the sense of smell. On the other hand, air impregnated with innocent odors may be exceedingly offensive to the nose. Deodorization, therefore, in itself is comparatively of little importance to health ; it may even do mischief by leading to the belief that an impure atmosphere is pure because it is inoffensive to the sense of smell. Most disinfectants are deodorants also, but this property is accidental not essential.

56. **Disinfectants** are substances which destroy or prevent the generation of atmospheric impurities injurious

---

* Suppose air and hydrogen to be the diffusing gases, the density of air is taken as unity and its diffusion-volume will be 1, the density of hydrogen is 0·0692 its diffusion-volume $= \frac{1}{\sqrt{0{\cdot}0692}} = \frac{1}{0{\cdot}2632} = 3{\cdot}7994$. Actual experiment gives 3·83. Thus if a body of air and a body of hydrogen are in communication 3·83 volumes of hydrogen pass into the air while one volume of air passes into the hydrogen.

to health. They may act by decomposing noxious gases or vapors, resolving them into harmless elements or combinations; or by arresting putrefactive and fermentative processes; or by killing the living germs of diseases; or by destroying organic poisons; or by favoring the rapid oxidation of putrescent matters. As some are efficient in more than one of these ways, it is not possible to classify disinfectants according to their modes of action; and the division into *solid*, *liquid* and *gaseous* is convenient though unscientific.

57. Of *solid* disinfectants **charcoal** is the best. It absorbs sulphuretted hydrogen and other aëriform products of the decomposition of organic matters. The volatile organic emanations of disease are similarly absorbed, and oxidized by means of the oxygen which is present in the pores of the charcoal. It has no direct effect on suspended impurities, but may remove some of the atmospheric conditions favorable to the growth of those which are organized and alive. It is a cheap and effective disinfectant, and should invariably be present in hospital-wards, latrines, sewers and other places where offensive and unwholesome gaseous effluvia exist. Its efficacy is proportional to the amount of surface exposed, and therefore, it should be sub-divided as minutely as possible. Hence, animal charcoal is a better form than ordinary wood-charcoal, and this, when used, should be broken up. Peat comes next to animal charcoal in suitability for disinfection. This power of charcoal is impaired or destroyed by use and restored by re-burning.

58. **Dry-earth**, especially if it includes calcareous matter and humus, is a powerful absorbent of offensive emanations, but considerably inferior to charcoal. It is incapable of destroying either the low forms of life or the organic poisons which propagate disease. It is not improbable that the latter may be protected from disintegration by earth, and may resume activity under favorable conditions, but, on the whole, the risk of propagation of disease by fæcal matter is diminished when the latter is thoroughly mixed with dry-earth. Dry-earth is a valuable deodorant, but its disinfecting power is small.

59. **Lime**, caustic or slaked, removes carbonic acid and offensive sulphur compounds from the air by entering into combination with them. In the former condition it destroys

all organic matter with which it comes in contact, and is, therefore, useful for obviating danger from putrescent animal substances as dead bodies and fæcal evacuations. The hydrate applied to buildings in the form of white-wash deodorizes and neutralizes, temporarily at least, the effects of such organic matter, living or dead, as may be adherent to the walls. It may, however, be used so as merely to conceal dirt and to cover without devitalizing organic poisons capable of becoming mischievous at a later time. Walls should be carefully scraped before a fresh coat of lime-wash is applied and the scrapings burned or buried. Lime arrests the alcoholic fermentation, but rather by precipitating the sugar than by destructive action on the ferment; so that its action in arresting other fermentative changes is doubtful.

60. The **carbolates** which constitute McDougall's Powder and similar preparations* are very valuable both as deodorants and disinfectants. They probably arrest putrefactive and fermentative changes, and destroy the organized products already formed, in the same manner as carbolic acid, while the earthy bases absorb the offensive effluvia.

61. **Chloralum,** as the impure aluminum chloride has been unfortunately called, is a deliquescent solid, capable of decomposing sulphuretted and phosphuretted hydrogen and ammonium sulphide. It is a powerful antiseptic and is itself inodorous. It is not poisonous. It will probably come into use extensively in this country. It may be applied in the solid state or in solution. Other soluble metallic chlorides are similarly useful.

62. **Liquid** disinfectants are more convenient in application than solid, as they can be dispersed more freely, and can be kept in concentrated solutions until required for use. Their effect is limited, like that of the former class, to the air immediately in contact with them, and it is, therefore, desirable to extend the exposed surfaces as much as possible by putting the liquids in broad, shallow vessels, or sprinkling them on cloths. **Ledoyen's fluid** is a solution of the lead nitrate, which rapidly decomposes sulphuretted hydrogen and is, therefore, adapted to the deodorization of sewers and cesspools. To prepare it a pound of

* McDougall's Powder consists mainly of calcium carbolate and magnesium sulphite: Calvert's of aluminum carbolate and silica.

litharge is mixed with a little water and about seven ounces of nitric acid gradually added. The result diluted to two gallons is poured into the offensive place.

63. **Burnett's fluid** is a solution of zinc chloride containing twenty-five grains to the dram. A pint of the fluid is diluted with a gallon of water for use. It decomposes sulphuretted hydrogen and ammonium sulphide, and by its caustic properties destroys organic matter. The application of this chloride to stumps and other wounds has been attended with excellent results, in diminishing suppuration and the danger of unhealthy action arising from organic poison or germs floating in the air. The solution thus employed contains 40 grains in an ounce. The fluid itself is a corrosive poison.

64. The zinc and iron **sulphates** both decompose the offensive sulphur compounds before mentioned and also prevent zymotic development, that is the formation of those products of fermentative putrefaction which give rise to non-specific diseases. The same may be said of the **ferric chloride.** In this case the deodorizing result is aided by the ferric oxide derived from the decomposition of the ferric sulphide first formed, which also acts upon sulphuretted hydrogen. **Condy's Fluid,** a solution of alkaline permanganates, acts by oxidizing organic matter and by decomposing ammonia compounds. Lastly, **carbolic** (or phenic) acid in solution completely arrests the putrefaction of dead organisms and kills the lower forms of life on which fermentation depends. It is supposed also to check suppuration and to suspend animation in the germs to which the propagation of many diseases, surgical and medical, is attributed. It is a very valuable antiseptic and a useful disinfectant, and will probably hold its present ground in the favor of hygienists to a considerable extent.* It has the disadvantages of being poisonous, and of being, in its commercial form, disagreeable in odor to many persons. The acid itself is inodorous.

65. A mixture of eight ounces of sulphate of iron with one ounce of carbolic acid and three gallons of water is recommended for the disinfection of the clothing &c. of scarlatina and variola patients. Solution of ferric chloride (sp. gr. 1·300) with ten parts of impure carbolic

* The Paris Morgue is deodorized by a continuous stream of carbolized water, containing 1 part of the acid in 4,000.

acid, largely diluted with water, is useful in latrines, sewers, confined rooms &c. A concentrated solution of the ferric sulphate may be used instead of the chloride.

66. Of the *gaseous* disinfectants **chlorine** is the most common. It decomposes sulphuretted hydrogen and ammonium sulphide by combining with their hydrogen, and is superior to other gases for this purpose. It destroys organic odors and, to a certain extent, organic matter, dead and living; but to be efficacious in this use it must be present in amount intolerable to the respiratory organs. A room to be effectually disinfected with chlorine must be cleared and fully ventilated afterwards. Mixed with air, even in small proportion, it is irritating when inhaled; in large quantity it is directly and powerfully poisonous. Its odor is penetrating and disagreeable, and its bleaching properties may be inconvenient in many cases. It may be disengaged in several ways. Chlorinated lime or soda, moistened with water or in damp air, slowly evolves chlorine. The substance is exposed in shallow dishes, or sprinkled about, so as to give as large a surface as possible. The gas may be extricated from a mixture of four parts by weight of commercial hydrochloric acid with one part of manganese dioxide (the "black oxide") in powder; or from four parts of common salt, one of the dioxide, two of oil of vitriol and two of water, gently heated. By another method a solution is obtained from which the chlorine is gradually given off and which can be kept in a stoppered bottle for use as required. Mix one part by measure of red lead and four parts of common salt with 160 of water and add by degrees four measures of oil of vitriol. Common salt thrown upon a brisk charcoal fire is a useful disinfectant.

67. **Iodine** vapor is a powerful deodorant, decomposing sulphuretted hydrogen, destroying putrid emanations and arresting putrefaction. Its presence in wards where small-pox cases are lying, or sloughing or profuse suppuration is going on, adds greatly to the comfort and somewhat to the sanitary improvement of the inmates. A dram of the substance suspended from the ceiling will disappear by slow sublimation, and this mode of using iodine is adapted for general application in hospitals. If rapid evolution of the vapor is required it may be effected by throwing the solid on a hot plate or on hot coals; or a saturated solution in water may be dispersed as spray.

68. **Bromine** has been found useful for the same purposes as iodine, but it is dearer, the vapor is highly irritant, and its use demands care to prevent excessive evolution. Dissolved in solution of potassium bromide it is exposed in saucers to the air.

69. **Nitrous acid** has a powerful effect on organic matter, being an active oxidizer. Theoretically it imparts oxygen to putrescent substances, is converted into nitric oxide and immediately re-formed by combination of the latter with atmospheric oxygen. It thus destroys offensive organic vapors, and perhaps also living organisms ; and is well adapted for deodorizing places where dead bodies are exposed. It is highly irritant to lungs and air-passages and induces nausea and vomiting in some persons ; it is, therefore, not fit for use in occupied rooms. It is evolved by the action of oil of vitriol on nitre, or of nitric acid on copper; more slowly it is spontaneously extricated from diluted nitric acid.

70. Sulphur dioxide or **sulphurous acid** decomposes sulphuretted hydrogen and ammonia compounds. It arrests putrefaction and fermentation, and destroys the majority of offensive odors. It acts by deoxidizing. It affords a convenient means of disinfecting rooms in which cases of contagious and infectious disease have been treated; and, with the aid of heat, is probably the best disinfectant of clothing. Its irritant and suffocative effect when inhaled forbids its use to any valuable extent in occupied buildings. Hospital-wards should be cleared of inmates before fumigation with this or the previously described gas, and freely ventilated afterwards. It may easily be disengaged by throwing sulphur in powder on burning charcoal, or by setting fire to spirits of wine or tar poured over the sulphur.

71. **Ozone**, as has been already said, is a powerful oxidizer, and, therefore, may be expected to favor the disintegration and conversion into innoxious forms of dead organic material. Destructive action upon living germs or animalcules is not to be expected from it. The readiest method of preparation is placing a stick of phosphorus, partially immersed in water, in a wide-mouthed, stoppered, glass jar. The quantity of ozone thus formed can be estimated by test-papers, and the supply regulated so as to avoid excess, which would irritate if inhaled.

72. The vapor of **vinegar** diffused by sprinkling the liquid on a hot brick, or plate of iron, is deodorant and capable of neutralizing or decomposing ammoniacal compounds, of which many offensive gases consist. It can have no effect on organic matters, living or dead, and is therefore useless as a disinfectant. The form of vinegar called pyroligneous acid is more useful for this purpose on account of the tarry impurities which it contains.

73. While moderate **heat** favors putrefaction and the development of low organisms, a sufficiently high degree of temperature disintegrates and renders harmless dead organic poisons and destroys the vitality of living morbific germs. Heat, therefore, is a disinfectant of great power; but its application is difficult and inconvenient. Air which has been exposed to a strong heat has a scorched smell and is unpleasant, however safe, to breathe. Foul air may with advantage be conducted from a hospital-ward to an ordinary fire or a special furnace, where its capability of propagating disease may be effectually destroyed. It is very doubtful whether heat alone can be effectively employed for the disinfection of clothing &c.; some organisms at least being capable of resisting temperatures which cannot be exceeded without injury to the material, and there being no reason to suppose that organic poisons, other than germs or fully-developed animalcules, are more destructible than these. For this purpose heat should be applied along with some other disinfectant; and carbolic acid or soda if the fabric be boiled, or sulphurous acid if dry heat be preferred, will probably be the best. Every hospital should be provided with a disinfecting-chamber capable of being heated to 250° F. Few fabrics will resist so high a temperature as this.*

74. Our **choice** of a disinfectant will depend upon the nature of the poison to be neutralized or destroyed. This may be either a noxious gas, or an organic miasm capable of generating some specific disease, or a living creature, animal or vegetable, endowed with similar power. Whether cholera, typhus, typhoid and other specific diseases are propagated by dead organic poisons or by living germs is not known and for our present purpose is of little consequence.

---

* For some interesting experimemts on this subject see *Parkes' Practical Hygiene*, 5th Edition, page 578, *n*.

The disinfectant destructive of the one will be fatal to the other; and the special powers of each have been indicated above.

75. There is danger of over-rating the efficacy of disinfectants and of allowing their use to supersede ventilation. They must always be considered subsidiary to this, the great means of purifying a foul atmosphere, and they can never be substituted for it. A comparison of the quantity of disinfectant employed with the volume of air which it is supposed to purify will show that, in many ordinary cases, no appreciable benefit should be expected from this means of purification.

76. VENTILATION is the supply of abundance of air of normal purity to places inhabited by men or other animals. It will be considered here chiefly with reference to dwellings, temporary or permanent; but courts and streets, compounds and cantonments, villages and cities, need free ventilation no less than rooms and houses. The points to be examined are: The *quantity* of pure air necessary to health, the *means* of providing the amount required, the *measurement* of the supply, and the conditions essential to effective *distribution.*

77. The removal or dilution of the products of respiration is the first consideration. The quantity of air vitiated by each respiratory act of an adult human being may be estimated at 30 cubic inches. Sixteen respirations per minute, therefore, destroy 480 cubic inches in that time, and 28,800, or 16·66 cubic feet, in an hour. Respired air contains 40 volumes of carbonic acid in a thousand; normal air 0·4, one hundredth part. It follows that in order to dilute air thus vitiated, to such a degree that it shall include no more than the average proportion of carbonic acid, it would be necessary to supply 100 times as much air containing no carbonic acid as has been discharged from the lungs, *i.e.*, 1,666 cubic feet per hour for each person. But normal air contains some carbonic acid; and respired air includes not only carbonic acid in excess but also aqueous vapor to saturation and an unknown amount of fœtid organic matters. The skin, moreover, contributes its exhalations to the atmospheric impurity. Adding about a quarter to the quantity calculated above, on account of these other sources of impurity, we conclude that the *minimum* of normal air

required to maintain in a condition of purity the atmosphere of a place occupied by healthy human beings is 2,000 cubic feet per hour for each individual. The corresponding number for a horse may be stated at 2,500. Experiment has confirmed these results of calculation.*

78. A higher estimate of the amount of normal air required is deduced from **de Chaumont's formula,**

$$d = c\frac{r' - r}{r - R};$$

in which d is the number of cubic feet of pure air required; c is the capacity of the room; r' is the increase of carbonic acid in one cubic foot of air, due to the respiration of one adult male in one hour (taken as 0·6 cubic feet); r is the amount of carbonic acid (taken as 0·6 per 1,000) to which r is to be reduced; and R is the normal quantity of carbonic acid in air (0·4 per 1,000). On this formula the following table is based.†

Cubic feet of space per man.	CO_2 per 1,000 due to one hour's respiration.	Cubic feet of air required to reduce CO_2 to 0·6 per 1,000.
100	6·00	2,900
200	3·00	2,800
300	2·00	2,700
400	1·50	2,600
500	1·20	2,500
600	1·00	2,400
700	0·85	2,300
800	0·75	2,200
900	0·66	2,100
1,000	0·60	2,000

The third column gives the requirement for the first hour; 3,000 cubic feet being required for each succeeding hour.

79. In these calculations the proportion of carbonic acid is taken as the index of the amount of respiratory impurity; and it is assumed that this proportion should never exceed 0·6 per 1,000. It has been ascertained that when this ratio has been reached the offensive odor of respiratory and cutaneous organic exhalations begins to be perceptible to the smell.

* The minimum laid down by the Barrack Commissioners is 1,200 cubic feet per man per hour in barrack-rooms, which, however, are not constantly occupied by all the men calculated for.

† Vide *Parkes' Practical Hygiene*, 5th Edition, page 143.

80. Hospitals or other places occupied by the sick demand a higher minimum of supply. In some diseases the amount of organic exhalations is so large that it is almost impossible to give pure air enough to remove their characteristic odors. A ward containing many cases with open wounds requires at least 4,500 cubic feet of fresh air per man per hour. When hospital gangrene, pyæmia, erysipelas, typhus, variola or plague prevails the supply of air should be limited only by the necessity of protecting the patients from wet or excessive cold. In such cases free ventilation not only promotes the recovery of the sick but also opposes the spread of disease. It has been observed that the organic poisons of some diseases are more capable of destruction by oxidation, or dilution to harmlessness, by pure air than those of others. Thus, a few feet of freely ventilated space suffice to protect from the poisons of typhus and of plague; while variola and scarlatina spread in spite of abundant air-supply, and the diseases are communicable after even months of free exposure to pure air. Malaria is very slowly oxidized and may be conveyed by winds considerable distances, even many miles, from its source.* Some suppose that the cholera poison also is capable of being carried by winds without losing its virulence.

81. Provision has also to be made for combustion and its consequences. Air must be supplied in sufficient quantity to yield oxygen for fires and lights, and to dilute the gases resulting from combustion when these are permitted to escape into a room. 240 cubic feet of air should be allowed for the complete combustion of 1 lb. of *coal;* 120 for 1 lb. of dry *wood*, the carbonic acid and other gases produced escaping by the chimney. A cubic foot of *coal-gas* requires 8 cubic feet of air for combustion; therefore, about 25 should be allowed per hour for each burner, without taking into consideration the vitiation of the atmosphere of the room by the products of combustion, which should, if possible, be conducted immediately and separately to the open air. As a cubic foot of coal-gas generates when burnt about two cubic feet of carbonic acid, an ordinary burner adds six cubic feet of this gas

* Thus the north-east wind blowing over the Godavari District from the jungles, many miles away, brings malarious fever with it.

per hour to the atmosphere of the room, to compensate which 5,000 cubic feet of normal air must be supplied, unless the special outlets be provided. An ordinary *oil-lamp* generates about half a cubic foot of carbonic acid per hour, requiring 400 cubic feet of air for dilution. For a good *candle* 500 feet per hour should be allowed.

82. The **means** of supplying the requisite amount of pure air may be divided into natural and artificial: the former including *perflation*, *aspiration* and *circulation*; the latter, *extraction* and *propulsion*.

83. **Perflation** is the blowing of a natural stream of pure air through a room or other space. General perflation by the passage of wind through doors and windows or other openings is the most efficient means of ventilation and that which is best suited to this country and climate. A current of air moving at the rate of two miles per hour—a rate which does not produce a perceptible draught—through a door-way ten feet by four in area supplies 422,400 cubic feet of air per hour, a quantity sufficient for 200 healthy men. A stronger wind will pass readily through a tent-wall, or through matting; and perflation takes place to some extent through single planks of wood and even through unplastered porous brick if the velocity of the current be high. Doors and windows should always be so arranged as to permit free perflation when the wind is only moderately strong.

84. It is desirable that the movement of the air blowing through a room should be nearly or almost imperceptible to sensation, so that there shall be no draught or chill. Air may be moving at a rate of a mile or even a mile and a half per hour while no movement is perceived. Imperceptibility of movement depends not only on velocity but upon temperature; and the higher the latter the more rapid may be the rate without inconvenience. With the thermometer at 21° (70° F.) or upwards perflation at a considerable rate of velocity is attended by no sensation of chill. Even at lower temperatures than are ordinarily experienced in this country a velocity of a mile per hour is imperceptible, and a rate of a mile and a half is not disagreeable. It may be taken as a general rule that the rate of movement should not exceed 3·5 feet per second, *i.e.*, 2·4 miles per hour; and a lower rate will be objectionable if the air be moist or if it be of lower temperature than that it replaces.

85. There is another, but a less efficient and manageable, way in which perflation may be applied. Cowls turned towards the direction from which a wind is blowing may be placed at the top of a building, from which pipes of wood or metal convey the air received to rooms below. Direct communication between the cowls and the apartments to be ventilated is liable to be attended by draughts; but the streams of air can be conducted to the basement story of a house, there warmed or cooled as may be desired, and thence distributed by tubes to other parts of the building. Corresponding outlet pipes and openings, with cowls turned *from* the wind, will be provided for the issue of air commensurate with that blown in; and these by their aspirating effect will aid in ventilation.

86. This second mode of perflation is applicable to the holds of **ships**, which the direct method cannot reach. A funnel of canvas, wood or metal receives the wind and a tube conducts it downwards. Distribution without draught is difficult here as in a house. The force of the in-blowing current may be reduced by having the conducting tube bent at right angles, once or oftener; or by interposing screens of perforated zinc in the passage; but ventilation is impeded in proportion as friction is increased by these expedients and the plates are liable to become clogged with dust and are with difficulty got at for cleaning. The stream of air admitted by this method may also be regulated by valves.

87. **Aspiration** is the drawing of air out of a room or building through a shaft by means of the wind blowing at right angles to the latter. In this way a small current of air moving with a high velocity over the upper end of a tube, provided with a cowl turned *from* the wind, influences a large body of air below, by producing an upward draught.* This method withdraws air from a room and provision must be made for free admission of pure air in compensation. The stronger the wind the more copious will be the up-draught and the more effective the aspiration, while a powerful blast cannot, as we have seen, be borne in perflation. Neither method, of course, is applicable

* The little instrument used for raising and dispersing perfumed waters from a bottle, by blowing strongly in a direction at right angles to a tube inserted in the liquid, clearly illustrates *aspiration*.

where the outer air is absolutely stagnant, and ventilation will then depend upon either circulation or artificial means. It is also to be borne in mind that wind may impede ventilation by blowing across unprotected exit-openings, or down chimneys or other shafts.

88. The movement of air caused by differences of temperature is called **circulation.** Air heated by lights or fires or the bodies of men or other animals becomes lighter, rises and is replaced by colder air from above or from without, which is in turn warmed and similarly replaced. As this circulation depends upon the generation of a higher temperature within a room than that of the outer air and is active in proportion as the former exceeds the latter, ventilation by this means is chiefly applicable to cold climates and to rooms or buildings artificially warmed. For the same reasons it is more effective in proportion to the coldness of the external atmosphere. In all inhabited rooms, however, it needs to be taken into consideration and due provision made for ingress and egress of air.*

89. When this circulation is maintained, not by the ordinary sources of heat but by special contrivances, it forms one of the *artificial* means of ventilation; namely, that by **extraction.** In an ordinary chimney, when a fire is burning below, an upward current of air, moving at a rate of from three to six feet per second, is produced; and if the fire be very large a velocity of nine feet per second may be attained. Equilibrium will be restored by streams passing from other openings towards the fire-place, or, if there be no such openings, by a down-draught in the chimney itself, simultaneous with the up-draught. This principle is applied on the large scale to the ventilation of mines, where a large fire burning at the bottom of a shaft maintains a powerful upward current, while fresh air from the surface, descending through other openings, supplies the place of that withdrawn. In like manner large buildings are sometimes ventilated. A fire or a number of gas-burners or pipes filled with hot water heat the air at the lower part of a central shaft, in communication with each room by a pipe entering below.

* When, in very hot weather, houses are closed in the early morning the air within is, during a great part of the day, cooler than that outside; so that circulation is, in this way also, established.

90. Several **disadvantages** attend this mode of ventilating a building. Heat supplied by a fire, which is the source most generally available, is not easily kept at a fixed temperature or regulated to suit the varying circumstances of different rooms; if, from any cause, the requisite up-draught is not maintained from below, a down-draught will be generated in the shaft, which may bring with it into the building smoke or products of combustion; and, as this method only provides for extraction of air from the building, that which is thus withdrawn may be replaced by air entering from any source, as for instance from sewers or through water-closets.

91. Extraction by a screw-shaped **fan** has been suggested and practised; but the mechanical power which it requires could be more economically and efficiently applied to ventilation by propulsion.

92. **Propulsion** is the forcing in of pure air by mechanical means, either directly or through flues constructed for the purpose. When labor is cheap and thorough ventilation by natural methods not attainable propulsion may be applied with great advantage. The quantity of air thrown in can readily be measured and regulated, and its temperature raised or lowered. The common *thermantidote* is a familiar instance of this method. It supplies a constant stream of pure air to a room or building, which may be passed through a moistened tatty and thereby cooled. The mechanism of the machine is simple and not easily deranged, and little labor is required for working it; but the distribution of the supply is generally faulty. Air enters at a high velocity and is liable to pass through a room in streams to the outlets instead of intermixing, thus producing draughts.

93. Distribution can be more satisfactorily managed on the large scale as in what is called the **plenum method.** Large fans, worked by men or cattle or steam-power, force air drawn through a shaft, at least forty feet high and situated well away from all buildings, (to ensure purity of supply), into flues which communicate by branches and pipes with every part of a large building. This plan is suitable to a jail* if the absence of wind for long periods

* Mr. Stuart Clark introduced his "plenum method" into Agra Jail. One fan, 3½ feet in diameter, worked by hand at a speed of less than

renders natural ventilation insufficient, cheap labor being superabundant; but the first cost of machinery and buildings must be considerable. Its inventor suggests that canvas shafts may be substituted for masonry flues in applying this method to buildings; and also that portable fans, &c., should accompany troops marching in hot seasons, for the ventilation of tents.*

94. To ascertain whether sufficient provision has been made for the ventilation of any room the number of occupants and the volume of fresh air entering the room per hour, either by natural or artificial means, must be known. Dividing the latter quantity (after reductions for lights, fires, &c.,) expressed in cubic feet, by the former, the volume of pure air supplied for each person is obtained for comparison with the quantity stated above to be necessary. The amount of entering air is determined by the anemometer, or, in the case of ventilation by circulation, by calculation.

95. The **anemometer** is an instrument which shows the velocity of a current of air in feet per second. The openings through which air enters having been ascertained by the deflection of a candle-flame, or by the direction taken by the smoke of smouldering brown paper, the rate of the entering current at each is determined. The rate per second multiplied by 3,600 gives the rate per hour; and the product of this by the area of an opening in feet is

300 revolutions per minute, was found sufficient to ventilate a corridor 283 feet in length with 68 cells opening from it. The machinery is placed to windward, about 300 feet from the middle of the line of buildings. An underground main-flue of masonry, 4½ feet by 3, conveys the air to the jail. Smaller flues (2½ × 2 feet) pass under the floor of each block, and from these diffusion-pipes of earthenware, 9 inches in diameter, are distributed through the walls, communicating with the rooms by openings covered with perforated zinc. Besides the diffusion-pipes "diffusion cases" are placed over the central flue and connected with it, 20 feet apart, in each building.

* The *punkah* is not an instrument of ventilation except to a very limited extent. Its movement displaces and so produces a current which may draw air from without, but which in most cases is supplied by air like itself from within the room. A punkah promotes intermixture and diffusion; when the temperature is lower than that of the body it cools, by removing the layer of heated, ill-conducting and vapor-loaded air from the surface, substituting a colder film and favoring evaporation; when the temperature is higher it acts only in the latter way. Its use is favorable to comfort and to health, but not by promoting ventilation.

the number of cubic feet per hour which that opening yields. The instrument should be placed as nearly as possible in the middle of the length of the passage and about two-fifths of the breadth from the side in order that the mean velocity may be given. It often happens that the outlet openings are less numerous than those of ingress of air, as, for instance, when a chimney discharges from a room a volume admitted by several inlets. It may then be more convenient to estimate the outgoing air, with which the supply will necessarily correspond. Casella's anemometer will be found best adapted to the purpose.

96. The rapidity with which the heated air of a room escapes from a discharge-opening above, in cases when ventilation depends on **circulation**, and, consequently, the volume of cooler air drawn in are estimated either by the anemometer as above, or by calculation. The height of the column of heated air, *i.e.*, the distance from the floor of the room to the discharge opening, the difference of temperature between the internal and external atmospheres, and the friction which retards the outgoing current in its passage are the elements to be taken into consideration. The following Table* includes the first two and assumes the diminution of velocity due to the last to be one-fourth.

97. The results obtained by the use of the table are only approximately true, on account of the variability of the amount of **friction** in the discharge-passage, which depends on the length, the diameter and the directness of the flue or tube and also on the velocity of the current, which varies with temperature. Friction varies directly as the length and inversely as the diameter of the passage. When this is bent friction increases proportionately to the sine of the angle of deviation from directness. In the same flue or tube it varies as the square of the velocity of the stream of air. If, therefore, the passage is long and narrow a further deduction of one-sixth should be made from the result given by the table; and if the tube is, in addition, very angular or much curved the use of the table is inexpedient.

* Abridged from that constructed by Professor Parkes.

98. TABLE.

Height of column. Feet.	Difference between external and internal temperature in degrees of Fahrenheit.													
	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	20°
10	88	102	114	125	135	144	153	161	169	176	183	190	197	228
11	92	107	119	131	141	151	160	169	177	185	192	200	207	239
12	96	111	125	136	147	158	167	176	185	193	201	209	216	249
13	100	116	130	140	153	164	174	183	192	201	209	217	225	259
14	104	120	135	147	159	170	181	190	200	209	217	225	233	269
15	108	125	139	153	165	176	187	197	207	216	225	233	241	279
16	111	129	144	158	170	182	193	204	213	223	232	241	249	288
17	115	133	148	162	176	188	199	210	220	230	239	248	257	297
18	118	136	153	167	181	193	205	216	226	237	246	255	264	305
19	121	140	157	172	186	198	210	222	233	243	253	262	272	314
20	125	144	161	176	190	204	216	228	239	249	259	269	279	322
21	128	147	165	181	195	209	221	233	245	255	266	276	286	330
22	131	151	169	185	200	214	226	239	250	261	272	282	292	338
23	134	154	173	189	204	218	232	244	256	267	278	289	299	345
24	136	158	176	193	209	223	237	249	261	273	284	295	305	353
25	139	161	180	197	213	227	241	254	267	279	290	301	312	360

99. This table gives the discharge of air in linear feet per minute for different distances from floor to outlet and for different excesses of temperature within over temperature without, *minus* a deduction of one-fourth for friction. The number thus obtained multiplied by the sectional area of the discharge aperture is the volume discharged per minute in cubic feet, which multiplied by 60 gives the discharge per hour. Take, for example, a barrack-room 12 feet high, with an aperture 0·75 square feet in or at the ceiling, the thermometer standing at 85° F. while the temperature outside was 80° F. The table gives 125 for these circumstances; and 125 × 0·75 × 60 = 5,625 cubic feet of air discharged per hour. This method of calculation is only applicable when wind does not interfere with regular outflow from the room.

100. The table has been constructed on the principle that a heated column of air (*a*), in free communication with a cooler column (*b*), is pressed upwards by (*b*) with a velocity equal to that which a body would acquire by falling through a space equal to the increase of height which (*a*) would undergo in consequence of its increase of temperature, *i.e.*, equal to 8 times the square root of the increase of height. Thus, in the example given above, the difference of temperature is 5°, which multiplied by 0·0020361, the co-efficient of expansion for each degree of Fahrenheit, and the product by 12 feet (the height of the unexpanded column) give 0·122166 feet as the increase of height. The square root of this decimal is 0·34952, which multiplied by 8 gives the rate of efflux in linear feet per second uncorrected for friction. Deducting one-fourth for this correction and multiplying by the sectional area of the aperture we got cubic feet per second, which are again multiplied by 3,600 for cubic feet per hour. Thus, 0·34952 × 8 = 2·79616, and this (less one-fourth for friction =) 2·14712 × 0·75 × 3·600 = 5,797 cubic feet per hour.

101. The conditions necessary for effective **distribution** of the air supplied in ventilation may be considered under two heads; namely, the *space* allowed for each individual, and the *openings* provided for the passage of the air.

102. It is obviously desirable that pure air entering a room should be distributed as equally as possible among the occupants and in such a manner that 3,000 cubic feet per man per hour should be introduced without creating draughts. Pettenkofer found that the air of a chamber of 434 cubic feet capacity might be renewed six times in an hour without draught. With this object it is usual to allot a certain cubic space and superficial area to each individual. In hospital-wards, work-shops and dormitories, where the position of each person is fixed, such an allotment, com-

bined with proper ventilation, secures to each free supply of air uncontaminated by the products of the respiration of others. In buildings occasionally or irregularly occupied, as churches, meeting-rooms, theatres &c., the amount of space is of less importance as a test of sufficiency of ventilation. In all cases there is a danger of over-rating the importance of space-allotment. In an ill-ventilated room abundant space can only postpone the consequences of deficient ventilation, and the most careful obedience to rules providing against overcrowding should never supersede examination into the quantity of pure air entering and the quality of the atmosphere within.

103. It is plain, however, that the less the space in proportion to the number of occupants of a room, the greater must be the quantity of air supplied in a given time. It is possible to ventilate sufficiently an overcrowded room, but the velocity of the entering air must be high and at a certain degree of overcrowding would be intolerable. Hence, the value of rules laying down minima of cubical and superficial space, and the importance of carefully observing them. Thus, it is ordered that in barrack-rooms in the plains 1,800 cubic and 90 superficial feet should be allotted to each man; in hill-stations 1,200 to 1,400 and 75; in European hospitals 2,400 and 120 in the plains; 1,600 to 1,800 and 102 in the hills; in Native hospitals 1,500 and 99; in Lock hospitals 100 superficial feet for Europeans and East Indians, 60 for Natives; in Jail-wards 648 cubic and 54 square feet.* To ascertain whether a given room fulfils such conditions its cubic contents (after certain deductions) and the area of its floor are to be divided by the number of its occupants.† Deficiency in cubic space is less likely to be hurtful than insufficient area

* In the latest English Poor Law Regulations on this subject the minima are 850 cubic feet for ordinary patients, 1,200 for puerperal or offensive cases, 700 for the infirm and aged occupying the room day and night (otherwise 500), for healthy adults 300. The common lodging-house allowance is 240 cubic and 30 superficial feet. The Dublin regulations for registered lodging-houses require 300 cubic feet for each person. The London School Board allotment is 9 or 10 feet superficial in rooms 13 feet high.

† The English Army Regulations allow a horse 1,605 cubic and 100 superficial feet. Sick horses have 1,900 and 137. Cattle should have 1,000 cubic feet.

and should therefore be preferred when there is a choice of evils.

104. **Measurements** should be made in feet and tenths. If a measure so divided is not readily obtainable one inch should be disregarded, two inches are counted as 0·15, three as 0·25, four as 0·30, five as 0·40, six as 0·50, seven as 0·60, eight as 0·65, nine as 0·75, ten as 0·80, and eleven as 0·90.

105. The product of two numbers gives the **area**, and in the most common case, that of a room having four sides and rectangular corners, the length of one wall is multiplied into that of another which forms an angle with it. If the floor-space is a *parallelogram*, not rectangular, one side multiplied by the perpendicular distance between it and the opposite side gives the area. If two sides are parallel, a third at right-angles to them and the fourth not, (forming a *trapezoid*,) the area is equal to half the sum of the parallel sides multiplied by the third. Other right-lined figures are divided into triangles by diagonal lines, the areas of which are found and added together; the area of a *triangle* being half the product of any side and its perpendicular distance from the angle opposite. The area of a *circle* is the diameter squared, multiplied by 0·7854; that of an *ellipse* the product of the longest and shortest diameter multiplied by the same decimal; that of a *segment* of a circle $= \frac{3pc}{2} + \frac{p^3}{2c}$; where c is the chord of the segment and p its greatest height.

106. In the case of a room with a flat ceiling and of uniform height the **cubic contents** are the product of the area by the height. In many cases there is a roof with *single* or *double slope*. In the former case the area is multiplied by half the sum of the greatest and least heights, *i.e.*, of the heights of the higher and lower walls. When there is a *gabled roof*, (as in an ordinary Native military hospital,) the cubic contents of the roof-portion are equal to half the product of the area by the height of that portion *i.e.*, the difference between height from ridge-pole to floor and height of walls. Sometimes the roof-portion of a room or tent is *pyramidal*, when its capacity is equal to the area multiplied by one-third the height of the pyramid. A *cone* is measured in the same way. The cubic contents of a

cylinder are equal to the area multiplied by the height; those of a *dome* to two-thirds of that product. The *bell-tent* (not in use in this country) is measured as a cone; and a form of hospital-tent (also unknown here) terminates in half cylinders surmounted by half-cones.

107. Having thus determined the capacity of a room or other space in cubic feet, with recesses or other additions not included in the general measurement, **deductions** are to be made for the bulkier articles of furniture and for the bodies of occupants. Large presses, chests of drawers &c., will be measured. In hospitals, barrack-rooms and bed-rooms 10 cubic feet are allowed for each set of bedding; and in all cases three cubic feet for each person.*

108. The **openings** with which ventilation is concerned are divisible into two groups: those of *inlet* or *adduction* through which pure air enters and those of *outlet or abduction* for the escape of vitiated air. The direction and force of the air currents and, therefore, the proper distribution of the supply depend upon the management of the openings and the mutual relations of the two classes. In warm climates it often happens that doors and windows supply all necessary ventilation without producing draughts or chill and in some cases pervious walls, as of mats or bamboo, allow of free perflation without disadvantage. In colder climates doors and windows must generally be closed, and other, special, openings provided for inlet, and for outlet if the chimney is not sufficient. In the colder parts of this country portions of walls of rooms may be formed of tiles so as to be freely pervious during the hot months, but requiring to be closed (as with movable wooden coverings) during the cold season, when other openings will be necessary for ventilation. The consideration of such special apertures, therefore, as well as of the ordinary openings of a room, tent or building is of great importance in ventilation. They may be examined with reference to *position*, *number*, *size* and *form*.

109. Inlet openings are to be selected or made in such **positions** that the entering air may not be polluted before

* Women and children do not require so much fresh air or so much cubic space as adult males; but abundance of pure air is so important that in the text and elsewhere no reduction is suggested on this account.

admission, as by marsh exhalations, sewer effluvia, emanations from latrines or water-closets, discharge from outlets of other rooms or buildings, &c.; secondly, equable distribution and thorough intermixture of the pure supply are essential. Hence, where perflation is possible, there should be doors and windows in opposite sides of the room. In other cases special inlets should be provided near the floor, unless when the supply is so cold that it cannot be borne with comfort and means of heating it artificially before entrance are not available; then it may be admitted at about ten feet from the floor and directed upwards so that falling subsequently by its greater weight it may be equally diffused through the atmosphere of the room. In our climate the floor openings will generally be found suitable. Respired air first rises; therefore outlet openings are provided at the upper part of the room, tent &c. In single-storey buildings with sloping roofs, as most of our hospitals, no arrangement can be better for discharge of vitiated air than properly protected ridge-openings along the entire top. As a general rule the highest outlet is that from which discharge is most rapid; but the application of artificial heat, whether specially for favoring egress of air or for other purposes, powerfully affects the rate of discharge through and position of outlets. Thus the chimney of a room in which a fire is burning is always the principal and often the sole channel of discharge; and heating an outlet-tube with gas, whatever its position, increases its effectiveness. Finally, the relative positions of inlets and outlets must be considered. It should not be possible for fresh air to escape, without intermixture, through an outlet placed too near the aperture by which it entered, and, generally, the opening should be so arranged that the movement of air in the room should be vertical, not horizontal; so that air vitiated by one person's respiration (or, in hospitals, by one patient's exhalations) should not pass across the position of another.

110. The **number** of inlet apertures will be determined by the necessity for equable distribution of the fresh air, so that whether they be the ordinary openings of the room, or specially provided for ventilation, they should be (if correspondent in size) at equal distances from each other. In hospital wards, barrack-rooms &c., each bed should have an inlet aperture. Provided the number of inlets is sufficient for proper distribution, that of outlets

is unimportant. An ordinary chimney, when a fire is burning, will give sufficient discharge for a room in which four or five persons breathe; and one large outlet, in other cases also, will suffice for a building which requires many inlets.

111. The **size** of special ventilatory openings will vary with the number of occupants of the room, the degree in which ventilation is dependent upon such apertures and the difference between internal and external temperatures, on which rapidity of circulation depends. In a case, for instance, where doors and windows are kept closed and their use as inlet openings is only subsidiary and accidental, if the efflux of air be estimated by means of the table given above at 12,000 cubic feet per hour through an aperture of one square foot, it is inferred that in a room of 15 feet in height and at 10° difference of temperatures, sufficient air for six men (at 2,000 cubic feet per hour) is supplied. Dividing a square foot by 6 we get 24 square inches (or an aperture of outlet of 4·9 inches square) for each man. Adding an equal size for corresponding inlet we conclude that the number of inmates of a room of 15 feet high dependent mainly for ventilation on the movement of air caused by a difference of temperatures within and without of 10°, multiplied by 48, gives the total size, in square inches, of the necessary inlet and outlet openings. For ordinary hospital wards the multiplier may be taken as 72. If the room be higher than 15 feet or the difference of external and internal temperatures more than 10° smaller openings will suffice; under opposite circumstances larger apertures will be necessary; and to provide for fluctuation of temperature the openings should be capable of increase or decrease in area. It must be remembered that friction is increased by increasing the number of openings affording a given sectional area, and allowance should be made accordingly.

112. As the outflowing air is warmer and therefore bulkier than the incoming, the apertures of exit should, theoretically, be somewhat larger than those of entrance and the proportion is sometimes given as 11 : 10; but in practice this is a point of no importance. As regards absolute size of the two classes of apertures it is laid down that the distribution of the entering air is most successful when each inlet does not exceed 48 to 60 square inches

(the allowance for two or three men), and each outlet is not more than a square foot in size (or sufficient for six men).*

113. Lastly, the **form** and management of ventilatory openings have to be considered. In the case of **perflation,** if the wind have a high velocity, means must be adopted for efficient distribution without the production of draughts. Windows should open at the top, or sloping from below upwards and inwards, so that the cooler entering air may be directed towards the roof or ceiling to sink equably by its superior weight. Or a window may be divided into sections each opening separately with such an upward slope. In windows opening in the ordinary way the requisite direction may be given to the stream of air by a sloping board. Some panes of the glazing may be double, with openings below in the outer and above in the inner glass; or one or more panes may be fitted with glass louvres. Some may have wire gauze or perforated zinc instead of glass; or movable frames with one of these materials may replace the sash when raised or thrown open.

114. The upper end of **aspirating** tubes and shafts should be protected from the entrance both of rain and of wind, while their special action is favored by widening the aperture so that its size exceeds considerably that of the passage itself. This expansion or cowl revolves, so that the opening is always turned from the direction of the wind, and its upper rim projects a little so as to exclude

* The Barrack Commissioners allow 11 square inches of outlet aperture for each healthy person occupying a room, *i.e.*, nearly a square foot for 12 men, in addition to the chimney. This may be taken as from 20 to 24 square inches per head for inlet and outlet, and the space should be doubled in hospitals.

In Netley Hospital the total inlet area in nine-patient wards (besides doors and windows) is 162 square inches, or 18 square inches per man; in fourteen-patient wards, 15½ square inches per man. The outlets are 17 and 16 square inches respectively. There is great difference of opinion among hygienists in this matter of inlet and outlet areas, probably due partly to variations in the difference of temperatures and partly to estimating with reference to cubic space. One authority lays down that a square inch of inlet should be allowed for 120 cubic feet, or 60 square inches for a room occupied by 12 men with 600 cubic feet per head. As to outlet Professor Parkes recommends 1 square inch of inlet for 60 cubic feet and for outlet 1 inch for 60 cubic feet on the ground floor, for 55 on first floors and 50 on second or for a one-storeyed building.

rain from the shaft. Louvred terminations to aspiration-shafts are apt to admit rain and also down-draughts, and aspiration is not so powerful as when a revolving cowl is employed. It is a good arrangement to make the shaft terminate in a revolving cylinder open at one side and moved by a vane so that its aperture shall always be away from the wind, the whole being protected by a fixed louvred covering.

115. When ventilation is dependent upon **circulation** *inlet* passages should be short so as to admit of being readily cleaned, as dirt lodging in them may communicate impurity to the entering air; externally the openings should be protected from the wind by hoods and provided with means for diminishing their aperture or closing them altogether should circumstances require; within the room, if they open above the heads of the occupants, they may expand in size and be directed upwards; if they enter near the floor, coverings of wire gauze or perforated zinc may be employed, care being taken that the meshes or perforations are not so small as to impede the free entrance of air, and that they do not get clogged with dirt. Mr. Tobin's method of introducing air may be useful in hill-stations: vertical tubes, communicating with the atmosphere without and terminating about four feet from the floor, admitting cool air in streams which rise for some distance and then fall over and descend. *Outlet* passages should be as direct as possible and should have smooth internal surfaces so that friction should be reduced to a minimum; they should be protected from cold, and, therefore, not exposed but carried through the walls. When convenient, outlet tubes should be heated. Thus gas-flames may be used expressly for this purpose; or, when a special tube is provided for removing the products of combustion of gas, an outlet shaft with openings near the ceiling may enclose it, with an interval between the two; in this way a double out-flow will be produced. The external apertures must be protected from rain, not only on account of the direct inconvenience which would arise from its admission, but also because the evaporation of moisture from any part of the passage tends to cool it and so interferes with outflow dependent upon difference of temperature. A cowl, revolving so as to be always turned from the wind, will serve to protect from rain and also to favor aspiration through the outlet, while

it prevents reverse perflation. For hot climates it is recommended that outlet shafts should rise some distance above the roof, the upper portion built of brick and blackened. Finally, it is to be borne in mind that an outlet may, under certain circumstances, become an inlet; and provision must be made for the proper distribution of the entering air, should this occur.

CHAPTER III.

WATER.

116. A sufficient supply of water for drinking, cooking, cleanliness of bodies and of clothes and for keeping sewers in a proper sanitary condition is quite as essential to health as purity of air. For the last purpose *quantity* alone needs to be considered; for cooking and washing the degree of *hardness* is the most important particular; while the kind and amount of *impurities* present in drinking water, their effects, the means of detecting, and of removing them when removable, demand careful examination, no less than the quantity which should be supplied. We shall first consider these IMPURITIES; secondly, the SOURCES of water-supply; thirdly, the QUANTITY required and that obtainable from them; fourthly, STORAGE and DISTRIBUTION; and lastly, the SEARCH for water in unknown localities.

117. It is neither necessary nor desirable that water used for drinking or other domestic purposes should be absolutely pure. Such water would be insipid and perhaps unwholesome. **Impurity** to a certain extent is practically inevitable and neither disagreeable to the taste nor injurious to the health. A good water then is not one which is chemically pure, but one which is transparent, colorless, odorless and tasteless, which holds in solution a sufficient amount of atmospheric air, which contains no suspended matters and no excess of total solids or of any particular substance dissolved. In the following pages, however, each foreign substance will be considered separately as an "impurity," *suspended* or *dissolved*.

118. **Suspended** impurities are *inorganic* or *organic*. The former may consist of very finely divided silica, clay, chalk, chalky marl, ferric oxide, magnesium carbonate or other mineral substances. Rivers, especially in time of flood, carry down variable quantities of suspended matters, mostly inorganic. Thus the Rhine water contains from 1·73 to 20 parts in 100,000; the Mississippi from 58·82 to 80·32; the Ganges from March to June 21·71, from June to October 194·3, from October to March 44·86; the mean proportion of

suspended matter being 86·86 in 100,000. Tank waters also, especially after rain, are turbid from this cause. Such waters containing suspended mineral matters in excess may produce diarrhœa, dysentery, and even ulceration of the intestine, to which persons not accustomed to their use will be more liable. *Organic* impurities are more varied and more important. The *débris* of animal and vegetable organisms; ova, seeds and germs; living animalcules and plants of a low order; fæcal and other excrementitious matters; the specific poisons by which cholera and many other diseases are propagated—all these may be amongst the impurities suspended in water. Even rain water may contain some of these, but all of them may be carried from the surface into tanks and rivers or washed into wells by floods or percolate into them through the soil. The choleraic diarrhœa which sometimes results from drinking water largely contaminated with sewage is partly due to suspended organic impurity, partly to dissolved. The following parasites are supposed to obtain entrance to their human host through drinking-water:—*Anchylostomum* (or *Sclerostoma*) *duodenale*, *Ascaris lumbricoides*, *Bilharzia hæmatobia*, *Bothriocephalus latus*, *Distoma hepaticum*, *Dochmius* (or *Strongylus*) *duodenalis*, *Filaria dracunculus** and *Filaria sanguinis hominis*. Minute leeches have in some cases been taken in with water and given trouble by fastening in the mouth, fauces or pharynx.

119. The presence of suspended impurities is **detected** by the eye, the water being put into a long glass vessel and viewed with transmitted light. In this way not only turbidity in general will be visible and its degree estimable, but the nature of the larger suspended particles, whether living forms or inanimate matter, may sometimes be ascertained. After rest for 24 hours suspended matter will have, in most cases, subsided; and the microscope will yield information as to its nature. By this means organized structure will be recognized; silica will be known by sharp angularity of the particles, chalk by their irregular roundness. Effervescence on the addition of a drop of

* For a remarkable illustration of the effect of an improved water-supply in diminishing the prevalence of this parasite, *see* a paper of Professor Cockerill's in *Proceedings of Sanitary Commissioner, Madras*, for 1876, page 281.

dilute hydrochloric acid to the incinerated sediment shows the presence of calcium or of magnesium carbonate: and, if further information be required, the usual tests, as hereafter described, can be used.

120. It is rarely necessary to **estimate** the amount of suspended matter; but, if it should be desirable, a measured quantity of the water is set aside in a tall graduated glass vessel until complete subsidence has taken place, for which 24 hours are generally sufficient time. Pour off as much as possible of the clear water, noting its amount. Evaporate the residue to dryness at 180° C.; weigh; deduct for amount of dissolved matters contained in measure of water not decanted;* difference is weight of total suspended substances in original volume of water. Incinerate; add a few drops of ammonium carbonate to re-carbonate lime &c., which may have been formed during incineration; dry and weigh. The result is the weight of fixed suspended matters; and the difference between the two weights obtained is the quantity of volatile, mainly organic, suspended matter. If the fixed residue be treated with dilute hydrochloric acid carbonates will be dissolved and the insoluble portion will consist principally of sand and clay. A rougher estimate may be made by finding total residue before and after filtration.

121. Subsidence and filtration are the means of **removing** suspended impurities, and some of their ill-effects may be obviated by boiling the water or by adding certain substances to it. Different impurities subside with different degrees of rapidity and completeness. Thus chalk and sand settle sooner than clay and are also more easily separated by filtration. Vegetable matter subsides slowly; and animal matter, especially that derived from sewage, being in a state of very fine division and specifically light, descends still more slowly. Both are readily removed by the filter. Sometimes finely divided clay is separable neither by spontaneous subsidence nor by ordinary filtration, as through sand and charcoal. A small quantity of powdered *alum*, six grains to the gallon, added to such water will generally, after 12 hours' rest, cause subsidence, a hydrate being formed and carrying with it in its own descent the suspended matter. Lime added in Clark's process for the purpose of softening water produces a precipitate which similarly carries down suspended impurities. The bruised nut of the *Strychnos potatorum* rubbed on the inside of the water-vessel, in the proportion of about 30 grains to 100 gallons, has the same effect in 24 hours. *Boiling* will destroy the vitality of some at least of the ova

* Known from a subsequent process (132).

or germs which neither subsidence nor filtration can remove and may also break up and render innocuous certain animal poisons capable of exciting specific diseases. *Astringents* containing tannin as kino, and especially tea, are also supposed to obviate in great measure the ill-effects of using turbid water.

122. **Dissolved** impurities may be gaseous or solid, the latter being organic or inorganic. The **gaseous** substances requiring to be noticed are *air*, *carbonic acid*, *ammonia*, *sulphuretted hydrogen* and *marsh-gas*.

123. The presence of **air**, or, to speak more correctly, of a variable mixture of oxygen and nitrogen, rarely containing the same proportions as the atmosphere, is necessary to render water palatable and readily digestible. The oxygen is more readily absorbed by water than the nitrogen and it is also evolved by certain water plants; hence it may amount to as much as 32 per cent. of the total quantity of both gases present. Neither can do any harm, while the oxygen is useful by converting decomposing animal and vegetable substances into innoxious compounds. Water is rarely deficient of air; but when (as in distilled water) there is a deficiency, it should be artificially supplied, either by forcing air into the water or by letting the latter fall in divided streams, as through holes bored in a cask, from as great a height as possible, through air. We may infer the presence of much oxygen if we have reason to believe that carbonic acid is present in abundance, unless in the case when the latter is formed from organic matter at the expense of the former. The actual *quantities* of oxygen and nitrogen can be approximately determined if necessary, as described in (125).

124. **Carbonic acid** gives a sparkling appearance and a pleasant taste to water, and it can only be injurious by enabling water to hold in solution large quantities of carbonates of calcium, magnesium &c. It may be derived (1) from decomposition of carbonates by subterranean heat, as in the case of carbonated springs; or (2) by absorption from the atmosphere, one volume of water at 20°·0 being capable of absorbing 0·901 of this gas; or (3) from the soil through which the water percolates, the air in which contains in some instances 250 times the normal proportion of carbonic acid; or (4) from the slow combination of the carbon of organic substances in the water with oxygen, in which

case it represents putrescible and possibly injurious matter destroyed. Its amount in ordinary water varies from 3 to 300 c. c. per litre. It is known to be present in considerable quantity when bubbles are seen on the inside of a glass vessel in which water is permitted to remain for some hours. Present in large amount it sometimes gives an acid reaction to test paper, the acidity being removed by boiling. Boiling removes it and the greater part of other gases; lime combines with it, the carbonate thus formed and other carbonates held in solution by it being precipitated.

125. Carbonic acid may be **estimated** approximately by means of the *soap-test*, which will be described hereafter. The hardness of water from which all calcium has been removed without boiling (precipitated by ammonium oxalate) may be taken to represent magnesium salts *and* free carbonic acid; that of water freed from calcium and boiled, magnesium only. The difference between the two hardnesses expresses carbonic acid, 1° of soap solution representing 0·00022 grm. If iron be present, it must be estimated separately and deducted, 1° representing 0·00014 grm. A more accurate determination may be made by boiling a known quantity of water for an hour in such a manner as to collect the gases expelled (over mercury) in a graduated glass vessel, showing, when corrected for temperature and pressure,* the total volume of gases dissolved in the water. Caustic potash (in solution of sp. gr. 1·4) passed into the vessel, combines with all the carbonic acid, and the diminution of total volume represents the volume of this gas present. Solution of pyrogallic acid† similarly inserted absorbs the *oxygen*, the volume of which is shown by the difference between second and third readings. The difference between the total corrected volume and the sum of the volumes of carbonic acid and oxygen is the *nitrogen*. Boiling, however, does not expel the whole of the latter gases.

126. Free **ammonia** is derived from the decomposition of nitrogenous organic matters, chiefly animal, in the water itself or in the soil through which it percolates, or from the atmosphere through which it falls. It is almost invariably present in ordinary waters. It is not in itself mischievous, but its presence in large amount indicates serious organic

* When a gas is collected over a liquid, the level of the latter inside and outside the inverted jar should be the same, or a preliminary "correction" applied. If the inner level is the higher, the gas is subjected to pressure less than observed barometric pressure, by amount necessary to support the column of liquid above outside level. Hence a correction is necessary in order to find true "observed" pressure. When (as in this case) mercury is used, the difference of level is subtracted from height of mercury in barometer. When the outer level is the higher the jar can be raised until the difference disappears.

† One part in six of water.

contamination. If present with nitrates or nitrites or both it is probably due to the decomposition of animal matters. If nitrites in abundance and ammonia coexist the contamination is probably recent. Its odor betrays its presence if the quantity be considerable. Turmeric paper browned by alkaline water recovers its color on exposure to the air if the alkalinity was due to free ammonia. A drop of Nessler's solution* added to the first portion of the product of distilling 500 c. c. with some solution of baryta gives a brownish yellow color if a very small quantity of ammonia was present and a precipitate if there was much. Filtration through charcoal will remove ammonia from water and, to a great extent, the organic matter which generates it.

127. The **estimation of free ammonia** is made by comparison of the color produced by Nessler's solution added to the water, distilled with certain precautions, with that of a solution of ammonium chloride of known strength. This standard solution contains 0·0315 grm. in a litre of distilled water, ascertained to be free from ammonia; so that the litre contains what corresponds to 0·01 grm.† of ammonia and each c. c. to 0·00001 grm. Distil in retort with Liebig's condenser 200 c. c. of the water, to which 15 c. c. of saturated solution of sodium carbonate have been added. Receive the first 50 c. c. of the distillate in a glass cylinder, and add 1·5 c. c. of Nessler's solution; ammonia if present will give the characteristic color. Into a second cylinder put as much of the standard solution of ammonium chloride as is likely to be required; add pure water to 50 c. c. and 1·5 c. c. of Nessler's solution. Compare the colors of the two cylinders, emptying the second and repeating the process if they do not exactly correspond, until both exhibit the same shade. Assume that the undistilled 150 c. c. of water contain one-third of the quantity of ammonia in the 50 c. c. examined. Each c. c. of standard solution required represents 0·00001 grm. of free ammonia in *one-fifth* of a litre of the water under examination, or 0·00005 in one litre. If urea be present, it will contribute an indeterminate quantity of ammonia in this process which will be reckoned as "free." Great care must be taken to ensure the perfect cleanness of the apparatus. A very pure water should yield no more than 0·000004 grm. (0·004 mgrm.) of free ammonia; Manchester water gave 0·006 mgrm.; water supplied by East London

---

* Put 35 grams of potassium iodide and 13 grams of mercuric chloride into about 800 c. c. of distilled water. Heat to boiling and stir until the salts are completely dissolved. Add cautiously a cold saturated solution of the same chloride until the mercuric iodide just begins to be permanent. Then add gradually 160 grains of potash, (or 120 grains of soda), to the solution and make up to one litre with distilled water. Lastly, add 5 c. c. of the saturated mercuric chloride solution and allow the deposit to subside.

† The equivalents of NH_4Cl and NH_3, (53·5 and 17) being *q.p.* in the ratio of 0·0315 to 0·0100.

Water Co., 0·030 mgrm., Thames water at Hampton Court, 0·045 mgrm., and a very impure well water 40 milligrams per litre.

128. When water contains a sulphate in solution (as that of calcium or of sodium) and also organic matter, the latter takes oxygen and converts the sulphate into a sulphide. This again being decomposed by a free acid, (probably organic, possibly by carbonic acid), **sulphuretted hydrogen** is the result; it is also one of the products of the putrefaction of albumen. Water in contact with it at 15° absorbs 3·23 volumes. The presence of this gas in drinking-water has been supposed to cause boils but the evidence for the supposition is not convincing. Diarrhœa also has been attributed to the use of such water but organic matter was probably present besides. The peculiar odor of this gas renders its presence even in small quantity readily perceptible, especially with the aid of gentle heat, and a solution of lead acetate in solution of soda gives a black or brown color with water which contains it. Boiling, agitation, exposure to air in divided streams, filtration through charcoal or addition of lime removes it from water.

129. Sulphuretted hydrogen can be **estimated** by means of a standard solution of iodine, containing 6·350 grms. dissolved (with the aid of a small quantity of potassium iodide) in a litre of water. A starch test-solution is prepared in the usual way and a little of it added to a litre of the water. The iodine solution is dropped in until a faint blue color appears.* Each c. c. of solution required to produce this effect represents 0·00085 grm. of sulphuretted hydrogen; multiplying which by the number of cubic centimeters used and the product by 0·00056† gives the corrected *volume* of the gas per litre.

130. **Marsh-gas** is evolved in the slow decomposition of vegetable matter, air being excluded; but is only very slightly soluble in water. It would be found in marsh waters; and certain foul river waters, that of the Thames for instance, undergo when kept for a few days a kind of fermentative purification, during which great part of their organic impurity is given off in the form of marsh-gas and

---

* $H_2S + I_2 = 2HI + S$; therefore, so long as H S is present in the water I is converted to HI and, being combined, does not affect the starch. The blue color shows that H_2S has disappeared. Each molecule of the gas requires a molecule of iodine; that is, 254 weights of the latter imply 34 of the former. 254 : 34 . . 0·00635 : 0·00085.

† A litre at 0° and 760 mm. weighs 1·51991 grm.; which : 0·00085 : : 1·000 ltr. : 0·00056.

sulphuretted hydrogen. It may leak into water from gas-pipes. There is no reason to suppose that its presence in drinking water is mischievous. Boiling or exposure to air in divided streams frees water from it.

131. Dissolved **solids** are organic or inorganic; the former being the more important. The nature of the substances in solution is of greater consequence than their total amount, but this also should be ascertained; both because it may be excessive and also as a check upon the detailed examination. It is not possible to lay down an absolute rule as to the quantity of total solids, irrespective of their quality, which is objectionable; but they may generally be considered excessive when they are more than half a gram per litre, although an excellent water may contain more than this.

132. The amount of **total solids** is ascertained by evaporating a known measure of water to dryness. The most convenient arrangement is a beaker containing water, in the mouth of which a platinum dish of 200 c. c. capacity can rest conveniently, a small piece of filter-paper being interposed between edge of beaker and dish, to allow free escape of steam. 100 c. c. of the water to be examined being poured into the dish, an ordinary lamp is applied to the beaker and the water in it boiled for a quarter of an hour after the contents of the dish are apparently dry. The dish is then removed, wiped externally, allowed to cool on an iron plate, under cover, and immediately weighed. The weight which the dish has gained, multiplied by 10, is the total solids in grams per litre. During the evaporation the dish should be protected as much as possible from dust. If the water contained magnesium chloride, as is certain to be the case when sea-water or sea-spray has had access to it, the deliquescence of this salt, causing it to absorb moisture from the air, renders accurate weighing of the residue very difficult. The addition of about 3 centigrams of calcined sodium carbonate to the 100 c. c. of water will obviate this difficulty by converting the chloride into carbonate; and the weight of the substance added must, of course, be deducted from that of the solid residue. The addition of sodium carbonate may cause the dissipation of some organic matter or ammonium salts; it is, therefore, desirable that it should not be made unless

there is reason to believe that magnesium chloride is present: which can be ascertained by holding a glass moistened with solution of nitrate of silver over the ignited dry residue of a small quantity of the water; a cloud of chloride of silver being produced if chloride of magnesium be present.

133. Part of the solid residue is fixed and part is **volatile,** the latter including organic matter, with ammonium salts, nitrites and nitrates which owe their origin to it, combined water and magnesium chloride. To estimate it, the dish containing the total residue is heated to redness; when it has cooled, a few drops of solution of ammonium carbonate are added (to restore any calcium carbonate which the heat may have decomposed); heat sufficient to dry the residue is applied; and the dish is again weighed, again heated below redness and reweighed: and the process repeated until a constant weight is obtained. The loss of weight represents the quantity of volatile (chiefly organic) impurity in a decilitre of the water. The origin and condition of the organic matter present are more important than its amount; and the determination of volatile solids is useful principally as a check upon other estimations.

134. The **behavior** of the residue during incineration gives a clue to a rough estimation of the quantity of organic matter present, (when means of accurate weighing are not at hand), and also to a judgment as to its nature. Thus, if the residue blacken perceptibly, it may be inferred that the water contains about 0·040 grm. of organic matter per litre; much charring implies about 0·080 grm.; copious, dark fumes, with scintillations in the residue, will indicate at least a decigram per litre. If there is much organic matter of *animal* origin, a peculiar and offensive odor will be developed during the process. Rapid whitening indicates nitrates.

135. The presence of **organic** matter in solution is almost inevitable. Even rain dissolves and carries down some from the atmosphere and water which has percolated through the purest granitic or clay-slate soils may contain (estimated as above) from four to ten milligrams per litre. Water collected from rich cultivated soils sometimes yields a volatile residue of 0·150 to 0·400, or even more, while this amount is considerably exceeded in peat waters and

marshes. In these cases the impurity is chiefly or wholly of *vegetable* origin, consisting of humin, ulmin and organic acids derived from these, none of which contain nitrogen, though the acids readily form ammonium salts when the base is supplied. *Animal* organic matter passes readily into waters derived from the neighbourhood of dwellings, which have washed or percolated through filth-soaked ground, or which have been polluted by communication with cess-pools or other accumulations of impurities. Dead animals slowly decompose in rivers, tanks and wells, and water from burial-grounds finds its way into sources of supply. Urea readily becomes ammonium carbonate, and a large proportion of the products of decomposition of animal substances contains nitrogen, which forms ammonia in the soil, and this is oxidized, with greater or less rapidity, to nitrous and nitric acids. Hence, water which has been exposed to pollution by animal impurities may contain in solution not only free ammonia but ammonium salts, nitrites and nitrates. Again, the decomposition of bodies of animals produces certain fatty acids, butyric and others, not nitrogenous, which form, with calcium and other bases of the soil, salts soluble in water; and these are probably not the least important dissolved impurities of organic origin.

136. The effects of dissolved organic impurities are not supposed to be so formidable as those of suspended; the latter including such diseases as are propagated by means of organized germs or spores; the former, those due to irritant poisons. Of the two classes of dissolved impurities of organic origin, the vegetable are certainly the less hurtful, and, indeed, it is doubtful whether any ill-effects can be traced to them. Putrescent animal matters, on the other hand, especially those arising from fæcal contamination, are often productive of serious consequences. The intestinal tract is most liable to disturbance, and diarrhœa and dysentery are not unfrequently due to this cause. The composition of the poison producing these results is not known; and it has often been observed that water abounding in organic matter, having been drunk for months or even years with impunity, has suddenly developed poisonous material. In some cases this may be due to unsuspected communication with a foul drain or cess-pool, suddenly established or enlarged: in others, unusual elevation of temperature may have concentrated the

water or set up putrefactive changes or may have favored the formation of the fatty acids which are known, even in minute amount, to be highly irritating to the bowels. Epidemics of dysentery or diarrhœa recurring annually in the hot season are probably attributable to one or other of these effects of heat upon drinking water. Diarrhœa may, in general, be expected if the water contains from 5 to 15 milligrams of putrescent animal organic matter; although larger amounts may be present in clear and sparkling water without apparent ill-effect, until the obscure putrefactive or fermentative changes mentioned above take place.* No doubt, other impurities are also present, and it is not possible to allocate definitely the share which animal organic impurity contributes to the production of intestinal irritation; but it may be laid down that the use of water containing this ingredient should never be permitted and that water contaminated by percolation through burial-grounds is the most noxious.

137. How far **specific diseases**, as enteric fever and cholera, are dependent upon *dissolved* organic inpurities cannot be stated. It is known that the former is propagated by water polluted with fæcal impurities, and that a large proportion of those who drink water containing the specific typhoid poison are attacked by the disease: but whether this poison is a possible product of fæcal sewage simply, or necessarily of sewage including the evacuations of enteric fever patients, is still an undecided question. It is stated that propagation by water is less common than by air but that the period of incubation is shorter, a large quantity of the poison obtaining entrance to the system and coming more immediately into contact with the intestinal tract. It may be that the specific means by which this disease is communicated is not a dissolved animal poison, but a suspended organized germ; and in this case putrescent animal products would favor its spread by exciting non-specific diarrhœa and acting as a predisposing cause. The same remark applies to *cholera*. Diarrhœa resulting from the use of water holding animal matters in solution increases susceptibility to the specific cholera-poison or cholera-germ.

---

* A case is reported in the *Lancet* of April 29th, 1871, in which an epidemic of diarrhœa in a girls' school is attributed to the use for *washing* of water which had stood for two years in a cask.

Either directly or indirectly, therefore, water thus polluted favors the spread of these specific diseases. It may be added that the diarrhœa resulting from water containing a large amount of putrescent animal matter is frequently choleraic in type and in severity.

138. For the **detection** of organic matter in solution, the *senses* are of little use. Peat-water contains much vegetable matter and is dark in color, and animal matters sometimes communicate a tinge to water in which they are dissolved; but depth of color is no test of degree of impurity. Nor will either taste or smell* indicate the presence of organic impurity, unless ammonia or sulphuretted hydrogen be amongst its products, or unless decomposing animal matter is present in large amount. Water holding in solution as much as three decigrams per litre may be colorless and unobjectionable in taste and odor. Recourse must, therefore, be had to other means of detection; and these are applicable either to the organic matter actually putrescent, or to the secondary results of its presence. The former is the hurtful ingredient in most instances; the latter (ammonia, free and albuminoid, nitrites, nitrates) are important as indicating certain past and possible future pollution.

139. Some of the organic matters in solution reduce the **gold terchloride**, precipitating the metal in the form of a purple powder. Hence this salt affords a means of detecting the presence, and of roughly estimating the quantity, of organic impurity. For this purpose a few drops in solution (which should be neutral) are boiled with 200 c. c. of the water for twenty minutes. The amount of precipitate which forms after rest indicates the quantity of organic matter; and animal substances are supposed to act more rapidly than vegetable.

140. The reduction of **potassium-permanganate** by oxidizable organic matter affords a better measure of the kind of impurity under consideration. The quantity of a

* Warming the water renders any peculiarity of odor more perceptible. Butyric and other fatty acids give out a characteristic offensive smell when water has been kept for some weeks in a stoppered bottle.

solution of that salt which is decolorized* by a litre of water gives a rough estimate of the degree of contamination with putrescent organic substances; and, as with the gold test, animal impurity is supposed to decolorize more rapidly than vegetable.

141. Accurate results can be obtained by the use of a standard solution† of the permanganate employed in the following manner: A litre of the water is acidulated with 1 c. c. of sulphuric acid, and the solution is added drop by drop, stirring after each addition, until a faintly pink tinge permanent for a minute is produced. From the number of cubic centimeters of permanganate solution deduct 0·6 c. c. (which is required to tinge a litre of pure water), and multiply the remainder by 0·0001. The result is the quantity of oxygen necessary for the oxidation of *readily oxidizable matters*. These include not only the immediate products of the putrefaction of organic substances but also sulphuretted hydrogen, nitrites and ferrous salts, the amounts of which must be estimated separately and allowed for. The amount of oxygen thus corrected should not exceed 0·00005 grm.

142. Organic matters **less readily oxidizable** are determined with the aid of heat. Add 2 c. c. of sulphuric acid to a litre of the water, and as much permanganate solution as the previous process showed to be required for readily oxidizable matter; heat to 60° (140° F.); remove lamp and drop in solution as before, stirring after each addition. Continue until a tinge permanent for half an hour is produced. If much organic matter is present the water may become brown and in that case a little more acid must be added. The total number of c. c. of solution used, less 0·6 c. c. as before, multiplied by 0·0001, gives total amount of oxygen required for oxidation.

143. It must be remembered that some organic substances escape, more or less completely, estimation by these processes. Amongst these are included urea, sulphuric acid, gum, starch, sugar and fats.

144. Closely connected with those of the organic matters in solution into the composition of which nitrogen enters, are ammonia, nitrous acid and nitric acid. The presence of any one of these implies, as a general rule, the previous solution of nitrogenous organic matter in the water.

* Certain substances take oxygen from the permanganate, decomposing it and, therefore, destroying its characteristic color and precipitating the manganous hydrate.

† This solution contains 0·395 grm. crystallized potassium permanganate in one litre of pure water. Its purity is ascertained by a test-solution of oxalic acid, containing 0·7875 grm. in a litre; of which 100 c. c., slightly heated with a little sulphuric acid, should decolorize completely 100 c. c. of the permanganate solution. Each c. c. of the latter represents 0·000395 grm. permanganate or 0·0001 grm. of oxygen. $2\ KMnO_4\ (316) = Mn_2O_3 + O_5\ (80)$; 80 : 316 : : 1 : 3·95.

Though, therefore, none of them (except, perhaps, the second) is directly injurious to health, it is important to ascertain their presence and amount. Free ammonia has been considered already. The presence of nitrites in large proportion indicates previous contamination with animal organic matter, probably recent. **Nitrous acid** is thus detected. Add a few drops of acetic acid to a mixture of solutions of starch and potassium iodide. Nitrous acid or a nitrite in the water will give a blue color (by setting iodine free) if 100 c. c. of it are added to the mixture.

145. The quantity of nitrous acid may be estimated approximately by means of the permanganate solution. Add 10 c. c. of dilute sulphuric acid to 500 c. c. of the water; boil for five minutes, to expel the nitrous acid; when cooled to 60°, test with permanganate. This gives total oxidizable matter, minus nitrites. The difference between the number of c. c. formerly required (142) and double that now used, multiplied by 0·0001875,* gives nitrous acid† approximately.

146. The presence of nitrates generally points to animal contamination. If no nitrites and little ammonia be present at the same time, the nitrates of potassium, sodium and calcium probably indicate that the contamination is of long previous occurrence. So, too, nitrates in abundance with little oxidizable matter, as shown by the permanganate, indicate old animal impurity. To detect **nitric acid**, the remains of the 500 c. c. of the water which, mixed with solution of baryta, (126) was distilled in the examination for ammonia is freed from baryta by addition of dilute sulphuric acid and filtration from barium sulphate. It is then concentrated to about 5 c. c., to which an equal volume of pure sulphuric is cautiously added. If a crystal of ferrous sulphate dropped into the mixture exhibits a brown color around it within a quarter of an hour, a nitrate was present in the water. Or the *brucine* test, which is one of exceeding delicacy, indicating the presence of so little as 0·0001 mgrm. per litre, may be used. 1 c. c. of a solution of a grain of brucine in a litre of pure water is added to 1 c. c. of the water under examination; 1 c. c. of pure sulphuric acid is poured down the side of the test-tube, so as to form a distinct layer under the water. If a

* Each c. c. represents 0·0001 grm. of oxygen, of which one atom oxidizes a molecule of NO_2 to NO_3. Therefore, 165 : 46 : : 0·0001 : 0·0001875.

† *i.e.*, NO_2 the acid element of a nitrite.

nitrate is present a pink tinge will appear at the junction of the two liquids. The sulphuric acid must in both tests be free from nitrous and nitric acid.

147. No convenient method for the **estimation** of *nitric* acid alone has yet been proposed. The amount of nitrous acid ascertained as first described may be deducted from the sum of nitrous and nitric acids calculated by the process following.

148. Nitrogen existing in water in **nitrites and nitrates** is estimated by conversion into ammonia, by means of aluminum and an alkali. A solution of soda (ascertained to be free from nitrates) is made, containing a hectogram to the litre. Of this 50 c. c. are added to 100 c. c. of the water and the mixture distilled in a non-tubulated retort, until the product is free from ammonia (as shown by Nessler's test), and the contents of the retort do not exceed 100 c. c. The retort having cooled, a piece of sheet aluminum is introduced; the neck is inclined a little upwards; and the mouth is closed with a cork through which passes the narrow end of a tube (1½ inch long and of about the diameter of a goose-quill) filled with pieces of clean tobacco-pipe moistened with very dilute hydrochloric acid, and connected with a second tube containing pumice-stone moistened with strong sulphuric. These precautions are taken to prevent the entry of ammonia from the atmosphere and great care must be observed to ensure the freedom of the apparatus from ammonia. That which exists free in the water may be expelled by boiling before the operation is begun. After twelve hours the contents of the pipe-clay tube are washed into the retort with distilled water, and a condenser, (carefully freed from ammonia by distilling water through it until the distillate gives no reaction with Nessler's solution), is attached, which dips below the surface of 80 c. c. of ammonia-free distilled water. Distil half the contents of the retort; make up distillate to 150 c. c. Apply the test to 50 c. c. of this; and if the ammonia is present in such quantity as to cause precipitation try another portion of distillate further diluted with distilled water. From the result the quantity of ammonia obtained from nitrites *and* nitrates in 100 c. c. of the water is calculated: and from this and result of (145) nitrates alone can be reduced.*

149. Having thus estimated the ammonia, free and combined, the nitrous and the nitric acids, it only remains to determine the amount of nitrogen present in other forms (except urea,) that is, as part of unoxidized organic nitrogenous matter. This nitrogen is converted into ammonia, which is called **albuminoid**, in the following way:—500 c. c. being put into a retort with sodium carbonate, 100 c. c. are distilled off and tested for free ammonia, as before described (127); then 50 c. c. of a solution of potash and potassium permanganate, made by dissolving 200 grams of the former and 8 of the latter in a litre of water and boiling to expel ammonia, are introduced into the retort. 200 c. c. are then distilled over and the ammonia estimated as before. It should not exceed 0·00008 grm. per litre.

---

* The quantity of NO_2 multiplied by 0·369565 gives the ammonia to which it corresponds, because 46 (NO_2) : 17 (NH_3) : : 1·000 : 0·369565. Deducting the ammonia corresponding to nitrous, the remainder (*a*) represents nitric. 17 : 62 (NO_3) : : 1·000 : 3·647. Therefore $a \times 3{\cdot}647$ = nitric acid in a decilitre.

150. It will be observed that no two of these methods of estimating the degree in which water is vitiated by organic matter deal with precisely the same impurity; and it follows that none of them should be relied on by itself. Incineration gives the amount of *volatile* matter, including animal and vegetable material, in various conditions of decomposition and decay, ammonium salts, nitrites, nitrates, combined water and also, not unfrequently, some inorganic salts as well. The permanganate tells us how much *oxidizable* matter is present, including putrescent organic substances and others. Distillation with sodium carbonate gives a result which includes *free ammonia*, *ammonium salts* and *urea*—substances indicative of sewage contamination. Distillation with aluminum and soda enables us to estimate, by conversion into ammonia, the amount of nitrogen (derived from nitrogenous, chiefly animal, matter) which has been oxidized either to *nitrous* or to *nitric* acid. By distillation with potash and potassium permanganate we determine the nitrogen of azotized matter not yet oxidized and still a constituent of *albuminous compounds*. The use of these five means, with the determination of the amount of *chlorine* present, gives us as much information as is attainable in the present state of our knowledge on the most important point of the fitness or unfitness of water for use. It may be added that neither subsidence nor filtration can be expected to remove all suspended organic matter from water: and that, therefore, the results obtained by these methods will not be due to *dissolved* impurity exclusively.

151. For the **purification** of water containing organic matters in solution *oxidation* is the great means. By it putrescent and other hurtful substances are converted into harmless products, as nitrates and ammonia and probably nitrites. Water freely exposed to air, especially if moving continually as in rivers, undergoes spontaneously but slowly this kind of purification. On a small scale, water in divided streams passing from one vessel to another loses by similar means its organic impurity. The potassium permanganate or Condy's Fluid supplies oxygen for the same purpose by its own decomposition. Filtration through charcoal, especially animal, acts similarly, bringing oxygen absorbed into its pores into intimate contact with the oxidizable organic matter. Filtration through the magnetic oxide of iron is supposed to remove

to remove the same impurity by chemical means; and iron wire and a mixture of ferric oxide and charcoal are said to have similar properties. Lime, strychnos potatorum and boiling may be employed if better means are not at hand. Nitrates are gradually removed by growing plants.

152. The **inorganic** dissolved impurities requiring notice are sodium, potassium, calcium, magnesium, iron and lead, in combination with chlorine, sulphuric, nitrous, nitric, phosphoric, carbonic or silicic acid.

153. **Chlorine** is almost invariably present in natural waters, in combination with the alkaline metals or calcium. Even rain water has been found to contain as much as 0·020 grm. of sodium chloride (0·012 grm. chlorine) per litre, derived from sea-spray which may be carried hundreds of miles inland by winds. This is one source of the presence of this salt in other waters ultimately derived from rain. Formations deposited originally in sea-beds retain the sea-salts, including magnesium, potassium, and especially sodium, chlorides: and occasionally the latter two are found in mass. Direct percolation from the sea is another source of chlorine in other waters. Lastly, sewage containing the excreta of men and animals includes a large proportion of sodium and other chlorides, which it imparts to water in contact or communication with it. It is owing to this last possible origin of chlorine in drinking waters that an exaggerated degree of importance has been attached to its presence. This is its least likely source, in this country at any rate ; and its derivation from such organic contamination will always be indicated by the accompanying presence of other products of sewage pollution. Its **effects** will be considered with reference to the *bases* with which it may be in combination.

154. The presence of chlorine is **detected** by means of a solution of silver nitrate. Add a few drops of dilute nitric acid to about 200 c. c. of the water; then some of a solution of silver nitrate. If chlorine is present the silver chloride, white and insoluble, is formed ; and from its appearance a rough estimate of the amount of chlorides present may be made. 15 milligrams per litre of sodium chloride produce a haze when the nitrate has fully decomposed it ; 6 centigrams cause decided turbidity ; a considerable precipitate will be formed with 0·140 grm.

155. Chlorine is accurately **estimated** in the following manner:—100 c. c. of the water are colored yellow with 2 or 3 c. c. of solution of pure neutral potassium chromate* containing 10 grams to the litre. A standard solution of silver nitrate, 0·479 grm, in the litre, is added drop by drop until the color changes from yellow to red, indicating that, the chlorine having all combined with the silver, the excess of the latter has formed the red silver chromate. Each c. c. of nitrate solution represents 0·1 mgrm. of chlorine†; therefore, the number of c. c. necessary to produce a red color in the water represents milligrams of chlorine per litre, 100 c. c. of water having been tested.

156. **Calcium** is the most important of the bases found in water, whether used for drinking, cooking or washing. It is the principal cause of *hardness*, which, if excessive, renders water unfit for culinary purposes and causes great waste of soap in the cleansing of the person or of clothes. Its salts, so far as our purpose is concerned, are the carbonate on one hand, removable almost completely by boiling, and the sulphate, chloride, nitrite, nitrate and butyrate on the other; the latter group (to which the hydrate may be added) remaining in solution after the carbonate has been precipitated. As water percolates through soils it dissolves out more or less completely the lime salts almost always present. Spring, well or river water, therefore, generally holds calcium compounds in solution, and even rain water is rarely free from traces of them derived from the atmosphere.

157. The **test** for the presence of lime salts in water is a solution of ammonium oxalate which throws down the whole of the calcium as oxalate, the water being first made neutral or faintly alkaline by ammonia. Turbidity following the addition of the solution shows that about a decigram per litre of some calcium salt is present: a considerable precipitate indicates about 0·250 grm.; and 0·400 grm. will give a large precipitate.

158. The total calcium may be **estimated** thus: To 250 c. c. of the water add ammonia until its odor is permanent after stirring (filtering if a precipitate results); a little ammonium chloride (to prevent possible precipitation of magnesium salts) and ammonium oxalate as long as it produces any cloud; stir and allow calcium oxalate to

---

* The chromate is often impure, containing chlorides. It is, therefore, desirable to ascertain how much standard silver solution is necessary to produce a decided red color when the chromate solution has been added to *pure* water: and a correction will be made accordingly.

† Because 170 ($AgNO_3$) : 35·5 (Cl.) : : 0·000479 : 0·0001.

subside; draw off as much of the clear water as possible and filter the remainder (retaining filtrate and water drawn off); wash oxalate on filter; cut filter with precipitate into small pieces and heat to dull redness for ten minutes in a plantinum dish or crucible, to convert calcium oxalate into carbonate; moisten with a few drops of strong solution of ammonium carbonate, to re-carbonate any caustic lime which may have been formed by excessive heat; dry, weigh, deducting for weight of ash of filter. The result multiplied by 1·6* is the weight of *calcium* in one litre of the water.

159. It has been already stated that calcium exists in water in two kinds of combination and the distinction is of great importance both from the sanitary and from the economic points of view. Calcium **carbonate** is soluble in pure water only to a slight extent, about 30 milligrams per litre, but is freely soluble in water holding carbonic acid in solution. Rain as it falls takes up this acid from the atmosphere, and, as it percolates through the soil, the interstices of which often contain air highly charged with carbonic acid, it absorbs still more. The water thus becomes a solvent of any carbonate of calcium (and also of carbonate of magnesium or of iron) which it meets in the soil. Hence the water of chalk or limestone formations holds always a considerable and sometimes a very large proportion of calcium carbonate in solution, by means of carbonic acid. The expulsion or neutralization of this acid necessarily destroys the solvency of the water, and, as this can be effected by boiling (which drives off the acid) or by adding lime (which combines with it) this lime salt is readily removable from water. Hence hardness depending on the presence of carbonates thus held in solution is called *removable* or *temporary* hardness; and, as calcium salts are the principal cause of total hardness, so calcium carbonate is the principal cause of temporary hardness.

160. Water may contain a very large quantity of calcium carbonate without **effects** either disagreeable to the taste† or directly hurtful to the health. Constipation has sometimes been attributed to excess of this impurity and there appears to be good reason to believe, though the evidence is conflicting and the conclusion still unestablished, that

---

* 100 ($Ca\,CO_3$) : 40 (Ca) : : *a* (weight of heated precipitate) : 0·4*a*. Therefore, weight of Ca in 250 c. c. = 0·4*a* : and in one litre = 1·6*a*.

† 15 centigrams per litre will be perceptible.

bronchocele and cretinism* are traceable to the presence of large proportions of calcium salts, including the carbonate, in the drinking water of the districts in which those diseases prevail. Urinary calculus is common in certain districts of England where the water is hard. Food, especially vegetables, is imperfectly cooked in such water, the carbonate being deposited on the surface as it boils and impeding the transmission of heat. Waste of soap will be considered hereafter.

161. The **presence** of this salt will be made evident by boiling the water for half an hour in a glass flask. The carbonic acid will be thus driven off and most of the carbonates present thrown down, so that the amount of turbidity or of precipitate will roughly indicate the proportion of removable to total calcium previously inquired into. Other carbonates, however, are thrown down also; and, therefore, a better opinion may be formed if the precipitate produced by boiling be collected on a filter, re-dissolved in dilute hydrochloric acid, and re-precipitated from solution, made up to original bulk with distilled water, by ammonia and ammonium oxalate—the same means of judging quantity being employed as before (157).

162. For accurate **estimation** of calcium carbonate the same method is applied to 250 c. c. of water. The precipitated calcium oxalate is converted to carbonate as before (158) and weighed. It may be considered excessive if there is more than 15 centigrams per litre.

163. One means of **removing** calcium carbonate, so far as its presence depends on free carbonic acid, has been already spoken of, namely, boiling for half an hour. Mr. Clark's process consists in adding lime to the water, which combines with the free carbonic acid to form carbonate, which, along with that which is now thrown out of solution, gradually subsides; carrying with it, as we have seen, organic and other matters in suspension. It must be borne in mind that this process removes temporary

* These affections generally co-exist; the latter appearing when from one-tenth to one-fifth of the human population is suffering from the former. The lower animals as dogs and cats, are liable to goitre. Excess of calcium and magnesium salts in the drinking water is supposed to act by causing early and excessive ossification at the base of the skull. By some, these diseases are attributed to iron pyrites or other metallic sulphide.

hardness only, while it adds slightly to the permanent hardness, to the extent of the lime which is taken into solution. It is applicable, therefore, to waters containing a large quantity of carbonates in solution and not containing an excess of other calcium salts.

164. The **other calcium salts**, which are not precipitated by boiling, are more important than the carbonate, because their effect upon the health, even in small quantities, is injurious; while they are equally objectionable economically. The sulphate is the most common, and water containing it is likely to produce dyspepsia, and diarrhœa following constipation. The chloride and the nitrate also irritate the alimentary mucous membrane; the nitrite has probably the same effect. Organic fatty matters undergoing putrefaction often generate butyric acid, which, itself highly irritating, combines with calcium to form a poisonous butyrate.

165. The **total** amount of soluble calcium salts is ascertained by applying the tests described above to water from which the carbonate has been precipitated by boiling. The permanent hardness of water is mainly due to these and the *soap test* (173), therefore, yields an approximate estimate of their amount. The quantity of each salt present is not of very great importance, but it may be ascertained from a complete quantitative analysis of the basylous and acidulous radicals present in the water. The *sulphate* should not exceed 5 milligrams per litre. About 350 milligrams of this salt, or 200 of the nitrate, may be present without being perceptible to taste.

166. **Magnesium** is a much rarer impurity than calcium; but it is found in water from several Madras stations. Its salts are second in importance, as causes of hardness, and are even more likely to produce intestinal derangement than equal quantities of those of calcium. When water is boiled to expel carbonic acid magnesium carbonate is deposited with calcium carbonate. As the water cools, the former is re-dissolved; and, therefore, it should be filtered hot if it is desired to separate the carbonate from the other salts of magnesium. When the mixed precipitate is dissolved in dilute hydrochloric acid and the calcium separated by precipitation and filtration, add ammonia, ammonium chloride and sodium phos-

phate; stir well and let the water stand for 24 hours. The presence of magnesium carbonate will be shown by the appearance of characteristic prismatic crystals of ammonium magnesium phosphate. The boiled water may be similarly treated to ascertain whether magnesium salts—the chloride and sulphate—are present; or the calcium may be removed from the original water, unboiled, and the magnesium thrown down as described.

167. To **estimate** magnesium the 250 c. c. of water from which all the calcium has been removed (158) are concentrated by evaporation, treated as in last paragraph with ammonia (in considerable excess) ammonium chloride and sodium phosphate, the crystalline precipitate is carefully collected on a filter washed with dilute ammonia, calcined with intense heat in a platinum dish or crucible to convert it to the magnesium *pyro-phosphate*. Allowance being made for the weight of the ash of the filter, the weight is multiplied by 0·8733* and the product is the quantity of magnesium in one litre of the water. Magnesium salts should not exceed 4 centigrams per litre.

168. **Iron** is a third cause of hardness. Few of our waters are altogether free from it and it is present in most cases as the carbonate, held in solution by free carbonic acid. It follows that it is thrown down by boiling, along with the calcium and magnesium carbonates; and when the precipitate is re-dissolved in dilute hydrochloric, a drop of potassium sulphocyanide added to 1 c. c. of the solution gives a red color if iron is present. *Taste* detects a smaller quantity of iron than of any other impurity, and it is said that 3 milligrams per litre give an appreciable chalybeate flavor. Excess of this impurity not only renders the water disagreeable to drink but also occasionally produces headache, constipation and other symptoms of dyspepsia. Boiling, lime and perhaps filtration remove it.

169. Iron is best **estimated** by the permanganate, having been first completely brought to the ferrous condition. As it is generally present in very small amount, it will be better to operate on the incinerated residue of a litre of the water with 10 c. c. of dilute sulphuric acid (1 part in 10). Dilute, after applying gentle heat for half an hour, to the original quantity with distilled water and pass a stream of sulphur dioxide through it (to reduce any ferric salts to ferrous); boil (to expel excess of gas) and add permanganate solution until a faint pink tinge is permanent. The number of cubic centimeters used,

* The pyro-phosphate is $Mg_2P_2O_7$, the numerical equivalent of which is 222·6. Weight found (a) : weight of magnesium contained : : 222·6 : : 48·6 (Mg_2); therefore, magnesium in 250 c. c. $= a \times 0{\cdot}21833$.

after deducting 0·6 c. c. (required to color pure water) multiplied by 0·0007* is the quantity of iron present in one litre.

170. The three bases now considered, with free acid (which acts by dissipating a *lather* already formed and which in this country is only likely to be carbonic) are the causes of **hardness**, and, therefore, this quality is a test of their presence and may be made a measure of their amount. Ordinary *soaps* are stearates (or oleates) either of potassium or sodium, soluble in pure water, and when dissolved enabling it to form a lather, or collection of more or less permanent bubbles, when shaken. When salts of the alkaline-earth metals (including magnesium) or of iron are present, the alkaline stearates are decomposed and insoluble stearates are formed instead, appearing as a curdy scum and ultimately as a precipitate. These insoluble stearates are useless for cleansing purposes and so much soap as is thus decomposed is wasted. Hardness, therefore, is a quality of great importance, economically in the first place and sanitarily in the second, inasmuch as any cause which renders cleanliness of clothes, dwellings and persons more expensive and more difficult of attainment is necessarily detrimental to health. Further, as on the addition of an alkaline stearate to water none will remain in solution, and consequently no lather will be possible, until the whole of the calcium, magnesium and iron salts have (in the absence of free acid) been converted into stearates, the quantity of soap which has to be added to a given quantity of water in order to produce a lather is a measure of the amount of calcium, magnesium and iron salts in solution; in other words, of the hardness of the water. The quantity of soap required is ascertained by using a standard soap solution.

171. A **standard lime solution** is first prepared, which contains 16 grains of calcium carbonate (or something equivalent) in a gallon of pure water. The hardness of this solution is said to be 16° of Clark's Scale; each degree of hardness representing, therefore, one-sixteenth of 0·229 grm. or 0·0143 grm. of the carbonate, or corresponding weight of any other hardening salt, per litre. There are several ways of preparing a solution of this strength; the simplest is to dissolve 0·393 grm. of pure *selenite*† (hydrated calcium sulphate) in a litre of distilled water; or the original method may be more convenient. Dissolve

---

* One atom of oxygen converts 2 FeO to Fe_2O_3 : and each c. c. of permanganate solution supplies 0·0001 grm. Hence 16(O) : 112 (Fe_2) : : 0·0001 : 0·0007.

† 100 $(Ca\ CO_3)$: 172 $(Ca\ SO_4,\ 2H_2O)$: : 0·22857 : 0·39314.

0·229 grm. of white marble or Iceland spar in pure hydrochloric acid, evaporate to dryness, dissolve in distilled water, again evaporate and repeat dissolution and evaporation until a perfectly neutral solution of calcium chloride is obtained; then add pure water to make up a litre. Or a standard solution may be prepared by dissolving 0·598 grm.* of pure barium nitrate in a litre of water, which will answer the same purposes as the lime solutions. In all three cases the solution may with advantage be made of 10 times the strengths indicated above and carefully diluted to standard when required for use.

172. The solution thus prepared is used for making the standard **soap solution.** Rub together in a mortar small quantities at a time of emplastrum plumbi and dry potassium carbonate, in the proportion of two parts to one. Potash (or soft) soap and lead carbonate are formed. Dissolve out the former with rectified spirit (about 90 per cent. of absolute alcohol,) using in repeated treatments about 30 times as much spirit as lead plaster. Let the solution stand some time and filter. Dilute with an equal volume of distilled water, and proceed to standardise thus.† Put 100 c. c. of standard lime solution into a 6-ounce stoppered bottle, add some soap solution from a graduated burette, shake the bottle for half a minute and see if a lather permanent for five minutes results. This effect should be produced by 32 c. c. of soap solution, so that if (as is probable) less is necessary the latter must be diluted with proof spirit until it is of such strength that 32 c. c. are required.‡ Great care must be used in this process of graduation. If it is accurately performed very valuable results are obtainable from the soap test.

173. Having now a standard soap solution, of which 32 c c. are necessary to produce a lather permanent for five minutes when briskly shaken with 100 c. c. of water containing 0·229 grm. per litre of calcium carbonate, or an equivalent quantity of other hardening salt,—water which, in other words, possesses 16° of hardness on Clark's Scale—the *total*, *permanent* and *temporary* **hardness** of any sample of water can be readily ascertained with the help of the table following. 100 c. c. of the water are put into the bottle and a few c. c. of the soap solution shaken with it. If no lather permanent for five minutes is produced, more solution is added and the shaking repeated. Thus the least quantity of soap solution necessary to produce

* 100 ($Ca\,CO_3$) : 261 ($Ba\,2NO_3$) : : 0·229 : 0·59769.

† A soap solution may be more easily prepared by dissolving some soft soap in equal parts of rectified spirit and distilled water, but the result is not so satisfactory.

‡ Suppose a permanent lather produced by 15 c. c. of soap solution of which 251 have been prepared, 15 : 32 : : 251 : 535·5. The solution will, therefore, be made up to 535·5 c. c. with proof spirit.

a permanent lather is found and the table gives the corresponding degree of *total* hardness. The experiment is repeated with water which has been boiled for half an hour, filtered while hot, made up to its original volume with distilled water and allowed to cool. This gives *permanent* hardness. The difference between the two represents *temporary* or removable hardness.

74

TABLE.

Degrees.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0° ..	1·4	1·58	1·76	1·94	2·12	2·30	2·48	2·66	2·84	3·02
1° ..	3·2	3·42	3·64	3·86	4·08	4·30	4·52	4·74	4·96	5·18
2° ..	5·4	5·62	5·84	6·05	6·28	6·50	6·72	6·94	7·16	7·38
3° ..	7·6	7·80	8·00	8·20	8·40	8·60	8·80	9·00	9·20	9·40
4° ..	9·6	9·80	10·00	10·20	10·40	10·60	10·80	11·00	11·20	11·40
5° ..	11·6	11·80	12·00	12·20	12·40	12·60	12·80	13·00	13·20	13·40
6° ..	13·6	13·80	14·00	14·20	14·40	14·60	14·80	15·00	15·20	15·40
7° ..	15·6	15·79	15·98	16·17	16·36	16·55	16·74	16·93	17·12	17·31
8° ..	17·5	17·69	17·88	18·07	18·26	18·45	18·64	18·83	19·02	19·21
9° ..	19·4	19·59	19·78	19·97	20·16	20·35	20·54	20·73	20·92	21·11
10° ..	21·3	21·48	21·66	21·84	22·02	22·20	22·38	22·56	22·74	22·92
11° ..	23·1	23·28	23·46	23·64	23·82	24·00	24·18	24·36	24·54	24·72
12° ..	24·9	25·08	25·26	25·44	25·62	25·80	25·98	26·16	26·34	26·52
13° ..	26·7	26·88	27·06	27·24	27·42	27·60	27·78	27·96	28·14	28·82
14° ..	28·5	28·68	28·86	29·04	29·22	29·40	29·58	29·76	29·94	30·12
15° ..	30·3	30·47	30·64	30·81	30·98	31·15	31·32	31·49	31·66	31·83
16° ..	32·0	..	..	..	..	..	..	..	..	..

175. It is obvious that water **exceeding** 16° of hardness must be diluted with an equal bulk of distilled water if it does not exceed 32°, and with twice its bulk if of more than 32° and less than 48°. The numbers obtained from the table will then be multiplied by 2 and 3 respectively.

176. It is not desirable to use for drinking water exceeding 5° of permanent hardness. The limit of desirable temporary hardness may be stated as 10°; but, as before pointed out, a much higher degree is not incompatible with health.

177. The primary use of the soap-test is the determination, for sanitary and economic purposes, of the total quantity of salts which produce hardness of water and of that portion of them which remains in solution when the water is boiled. It has, besides, a valuable **secondary use**, enabling us to make approximate estimations of certain bases and acids, and assisting us in determining the manner in which these are combined and in checking results obtained by other processes. Thus calcium, magnesium, sulphuric and carbonic acids may be approximately estimated. The last has been already considered (125).

178. If we determine the total hardness of a water, precipitate the **calcium** salts and again determine hardness; the difference represents the whole of the calcium. Care must be taken to avoid adding excess of ammonium oxalate which may itself be a cause of hardness. Each degree of hardness represents 0·01431 grm. calcium carbonate or 0·005724 grm. calcium. This decimal multiplied by difference between total hardness and hardness after precipitation of calcium, in degrees, gives amount of calcium present in the water.*

179. A similar method applied to the **magnesium** compounds gives less satisfactory results, partly in consequence of the variable composition of the compound formed with the fatty acid. The calcium is accurately precipitated from 200 c. c. of the water which is allowed to stand 24 hours, filtered, boiled for half an hour, (expelling or precipitating the ordinary causes of hardness other than magnesium) filtered and made up to original bulk with distilled water. The hardness is then determined after cooling. The number of degrees multiplied by 0·003477† gives, approximately only, magnesium in grams per litre.

180. Returning to the remaining bases, **potassium** is often present in small quantity, and may be estimated by first converting it and sodium together into chlorides and subsequently forming the double chloride of platinum and potassium. Evaporate 1,250 c. c. of the water in a dish to 200 c. c.; add 3 c. c. of milk of lime, heat for 5 minutes and wash the dish carefully into a flask holding 250 c. c. When cool, make up to 250 c. c., shake, allow to settle, filter. Add ammonium carbonate and oxalate to 200 c. c. of the filtrate (which now contains the solids of four-fifths of the original quantity, that is,

---

* 100 ($CaCO_3$) : 40 (Ca) : : 0·01431 : 0·005724.

† 100 ($CaCO_3$) : 243 (Mg) : : 0·01431 : 0·003477.

of one litre), make up to 250 c. c. and filter from subsided calcium oxalate. To 200 c. c. of the filtrate (equivalent to 800 c. c. of the original water) add ammonium chloride, evaporate to dryness and ignite. If little sulphuric acid is present the result is a mixture of potassium and sodium chlorides, the sulphates being converted by the ammonium chloride. If there is much sulphuric, barium chloride should be added, before the milk of lime, in quantity sufficient to precipitate the former, its amount being ascertained as hereafter described (190). Weigh the mixed chlorides, having ascertained that the residue is completely soluble in water, and that ammonia and ammonium carbonate give no precipitate (which would imply the presence of lime).

181. To **separate** the chlorides, dissolve in a little water; add aqueous solution of platinum tetrachloride in excess, evaporate nearly to dryness on a water-bath, treat the residue with alcohol of 80 per cent. strength, cover with a glass plate and leave for 6 hours, occasionally stirring. The supernatant fluid will be of a deep yellow color if enough of the platinum salt has been added; if it is not so, add more. The double chloride of *sodium* and platinum is dissolved in the alcohol, that of *potassium* and platinum appears as a yellow powder. Filter, wash with spirits of wine, dry at 100° and weigh. The weight (deducting for the filter) multiplied by 0·16* gives potassium present in 800 c. c.†

182. The **sodium** salts generally found in water are the chloride and the sulphate, and it is usual to suppose all the chlorine combined with sodium if the latter is present in sufficient quantity. The presence of common salt in water, unless largely in excess is, in itself, rather beneficial, especially in India, than injurious. It *may* be derived from sewage contamination, but in the majority of instances in this country it has no such origin. When so derived other evidences of pollution cannot fail to be present. In excess it may cause diarrhœa, as in a case where about 3·5 grams per litre were present; in amount not perceptible to taste (and less than a gram per litre is not perceived by most persons) its presence is of no consequence, except as a possible indication of sewage contamination. It may be partly *removed* from water by filtration through a considerable thickness of sand and charcoal, and in this way

---

* 488·7 ($2KCl, PtCl_4$) : 78·2 ($2K$) : : a (weight of double chloride) : x (weight of potassium). Therefore $x = a \times 0·16$.

† It should be ascertained that the *filtrate* contains no potassium. For this purpose, add to it some more platinum tetrachloride, evaporate to dryness and treat residue as before with strong spirit. If any double chloride appear, allow it to subside, decant off yellow fluid, wash repeatedly by decantation with small quantities of spirits of wine and transfer to filter containing the former precipitate.

brackish water may be rendered fit for use. The *sulphate* is not likely to be present in hurtful amount; it should not exceed a decigram. Its effect would be to produce a tendency to diarrhœa. The *carbonate* is sometimes found and spoils the water if it exceeds 3 decigrams. As much as 7 decigrams may be present without being perceptible to taste.

183. All or the greater part of the chlorine being in combination with sodium, the quantity of the former ascertained to be present affords an indication of the amount of the latter. Supposing all the chlorine and sodium to be present as sodium chloride, the quantity of chlorine found (155) multiplied by 1·648* would give the sodium chloride, and by 0·648† the sodium.

184. The sodium may be accurately estimated in two ways: either by the method described above (181), or by disregarding the potassium, (which is never present in large amount,) converting all the salts into sulphates, and making deduction from their total weight for the sulphates other than sodium sulphate, as previously determined. Knowing the weight of mixed potassium and sodium chlorides (for 800 c. c. of water), and having ascertained the quantity of potassium, this multiplied by 1·908‡ gives potassium chloride, which subtracted from weight of mixed chlorides and multiplied by 0·4915§ gives sodium in one litre. For the second method the incinerated residue of 100 c. c. of the water (133) will suffice. Add dilute sulphuric, apply gentle heat for 10 minutes, evaporate to dryness, add a little ammonium carbonate, dry, weigh The result may be taken as silica and the sulphates of iron, calcium, magnesium and sodium. Subtract from it the weights of silica (191); of iron (169) multiplied by 2·714‖; of calcium (158) multiplied by 3·4¶; and of magnesium (167) multiplied by 4·9506.** The remainder is sodium sulphate, which multiplied by 3·24†† gives *sodium* in one litre of the water.

---

* 35·5 (Cl) : 58·5 (Na Cl) : : 1 : 1·648.

† 35·5 : 23 : : 1 : 0·648.

‡ 39·1 (K) : 74·6 (KCl) : : a (weight of potassium in 800 c. c.) : x (corresponding weight of chloride.) Therefore $x = a \times 1{\cdot}908$.

§ 58·5 (Na Cl) : 23 (Na) : : b (weight of total chlorides in 800 c. c.—weight of potassium chloride) : y (sodium in 800 c. c.) Therefore, $y = b \times 0{\cdot}3932$, which multiplier becomes 0·4915 for 1000 c. c.

‖ 56 (Fe) : 152 ($Fe\,SO_4$) : : c (weight of iron) : z weight of ferrous sulphate). Therefore, $z = c \times 2{\cdot}714$.

¶ 136 ($Ca\,SO_4$) $\div$ 40 (Ca) $= 3{\cdot}4$.

** 120·3 ($Mg\,SO_4$) $\div$ 24·3 (Mg) $= 4{\cdot}9506$.

†† 142 $Na_2\,SO_4$: 46 (Na_2) : : a (weight of sodium sulphate obtained from 100 c. c. of water) : x (weight of sodium.) Therefore, $x = a \times 0{\cdot}324$; the multiplier becoming 3·24 for 1000 c. c.

185. It is necessary to speak of only one other base. **Lead** salts are not uncommonly found in water which has passed through leaden pipes or been kept in leaden cisterns. Commercial zinc generally contains lead, and its use for the storage or distribution of water is, therefore, open to the same objections as the employment of lead itself. The solvent action of water on lead depends upon the nature of the impurities which the former contains: water absolutely pure being itself, in the absence of air, incapable of acting on the metal. Any impurity which forms, directly or by decomposition, a soluble lead compound favors lead contamination. Thus water containing oxygen, air, organic acids (animal or vegetable), nitrites, nitrates or chlorides should not be kept in contact with lead. Hence rain-water, water containing sewage, or water which has lain on rich vegetable mud should not be conveyed or stored in lead. On the other hand an impurity which forms an insoluble lead salt, or which deposits a coating impervious to water upon the metallic surface, exercises protective influence against lead poisoning. In this way carbonic and sulphuric acids, or decomposable carbonates and sulphates, forming insoluble lead salts protect from the usual consequences of the presence of lead—with this exception, that if free carbonic acid is present it renders part of the lead carbonate soluble. Hard waters deposit a protective crust which is found to consist of the carbonates, sulphates and phosphates of lead, calcium and magnesium. Calcium phosphate is especially protective.

186. The consequences of lead poisoning are so well known that they need not be here described. The **quantity** of lead likely to produce intoxication necessarily varies with individual peculiarities, and in some cases 0·14 mgrm. of lead per litre is said to have been hurtful. As a rule, 0·7 mgrm. may be taken as the maximum admissible in wholesome water; but it is obviously much better that there should be none. When lead is present at all, accident, carelessness or mismanagement may readily cause increase in its amount from a harmless to an injurious degree.

187. Lead is **detected** by means of sulphuretted hydrogen. Boil some of the water, acidulated with sulphuric acid, and add saturated solution of sulphuretted hydrogen. A brown discoloration, caused by the formation of sulphide, indicates the presence of lead. If the quantity be very

small, concentrate the water by evaporation from half a litre or a litre to 100 c. c. It should be added that *copper* would cause a similar discoloration, but the presence of this impurity is so improbable that it need not be considered.

188. Lead may be **estimated** by means of a standard solution* containing 0·1 mgrm. in each c. c. Add to 400 c. c. of the water 4 c. c. of saturated solution of sulphurous acid and 1 c. c. of dilute sulphuric (1 part in 10); distil in a retort till 210 c. c. come over, testing the last few drops to ascertain their perfect freedom from sulphurous acid.† By this means any substance which might oxidize sulphuretted hydrogen and so cause a deposit not due to sulphide is removed. The contents of the retort being nearly cool, 100 c. c. are transferred to a glass cylinder and 5 c. c. of saturated solution of sulphuretted hydrogen added. A brown color, without precipitate for some minutes, is produced if lead be present, which is compared with that resulting from a similar treatment of standard solution. As much of this as is thought likely to be necessary is put into a second cylinder, which is filled to 100 c. c. with well-boiled distilled water, containing about as much sulphuric acid as the sample, and sulphuretted hydrogen solution added. If the colors correspond, the quantities of lead are equal; if they do not, the experiment must be repeated until they do, and this may be done three or four times before the color ceases to be clear. The standard solution must be mixed with the distilled water *before* the other solution is added; otherwise a precipitate will be formed. It is often sufficient to boil the water well before adding the sulphuretted hydrogen, without using sulphurous acid. By this process 1 part of lead in 750,000 parts of water can be detected, and the limits between which estimation can be made may be taken as 2 and 20 milligrams per litre. If the water contains much less than half the former quantity it must be concentrated before estimation.

189. The bases having been detected or determined, it remains to examine the water for the acids with which they are in combination. **Sulphuric** acid is tested for and roughly estimated by adding to a small quantity of the water a few drops of dilute hydrochloric acid and barium chloride in solution. If more than 0·020 grm. per litre of any sulphate is present a perceptible precipitate of barium

---

* Thus prepared. Dissolve 1 gram of lead acetate in about 200 c. c. of distilled water, adding a few drops of acetic acid to clear the solution; evaporate 50 c. c. to dryness in a weighed platinum dish with slight excess of pure sulphuric acid; when dry, ignite and weigh. The increase of weight is lead sulphate, from which the quantity of lead in 50 c. c. of the solution, and thence the strength of the solution, can be calculated. Take then as much of this as corresponds to 0·100 grm. of lead and make up to a litre with distilled water. Each c. c. of this solution represents 0·1 mgrm. of lead.

† By starch and potassium iodide solution.

sulphate is formed, either immediately or after 24 hours' rest. Four centigrams per litre will give an immediate haze and a distinct precipitate.

190. The accurate **estimation** of the acidulous radical is made by evaporating a litre of the water to about one-tenth and precipitating the barium sulphate as above, which is dried, ignited and weighed. The weight multiplied by 0·412 * represents the acid constituent of sulphates present. The *soap-test* also affords a convenient means of estimation, using a solution of barium nitrate corresponding in strength to the standard lime solution; that is to say, such that a litre corresponds to 16° of hardness (171). 50 c. c. of this solution are added to an equal quantity of the water, the total hardness of which is known, and after 24 hours the hardness of the mixture is ascertained. If no sulphuric acid is present, this hardness is equal to that of the original water *plus* that of the barium solution; if sulphuric acid is present, it will have precipitated a proportionate amount of barium and caused a corresponding loss of hardness. This loss in degrees, multiplied by 0·01374, gives the amount of sulphion in grams per litre.†

191. There is no reason to suppose that **silicic acid** is of any importance from a sanitary point of view. The incinerated residue of a known quantity of water, treated with hydrochloric acid, evaporated to dryness, repeatedly washed with hot water, dried and weighed, may be taken as silica and multiplied by 1·2666‡ to give the acid element of silicates.

192. Waters not unfrequently contain phosphates in solution and, as these may have been derived from sewage, or from animal remains as well as from harmless minerals in the soil, it is desirable to ascertain whether **phosphoric acid** is present. As in any case the quantity is small, the water must be highly concentrated before the test is applied. Add a few drops of dilute nitric acid, some strong solution of ammonium molybdate, boil. If phosphoric acid is present a yellow color and subsequently a yellow precipitate are produced by the formation of ammonium phosphoric molybdate, the amount of which indicates the quantity of phosphates present. Or, the phosphoric acid may be precipitated as ammonium magnesium phosphate by

* 233 ($Ba\,SO_4$) : 96 (SO_4) : : a (weight of barium sulphate) : x (weight of sulphion). Therefore, $x = a \times 0{\cdot}412$.

† 1° represents 0·037356 grm. of barium nitrate; or 0·01961 grm. of barium, because 261 ($Ba_2\,NO_3$) : 137 (Ba) : : 0·037356 : 0·01961. Each atom of barium combines with a molecule of sulphion, and 137 (Ba) : 96 (SO_4) : : 0·01961 : 0·01374.

‡ 60 (SiO_2) : 76 (SiO_3) : : a (weight of silica) : x (weight of acidulous radical.) Therefore, $x = a \times 1{\cdot}26666$.

adding to the concentrated water, filtered, some magnesium sulphate and ammonia in solution.

193. The **estimation** of phosphoric acid is occasionally necessary, and may be made as follows:—First, prepare a solution of ammonium molybdate by dissolving 10 grams in 40 c. c. of liquor ammoniæ of sp. gr. 0·960, with the aid of heat, and adding it to a mixture of 120 c. c. of nitric acid with 40 c. c. of distilled water; keep the whole at 40° C. for nine hours, allow time for subsidence and draw off the clear liquid. Treat the solid residue of one or two litres of the water, evaporated to dryness in a porcelain dish, with dilute nitric acid and filter (to remove silicic acid). Add about 40 parts of molybdic acid in the molybdate solution for one part of phosphoric acid supposed to be present in the acid solution prepared from the water; stir, without touching the sides; set aside for 12 hours in a temperature not exceeding 40° C. Remove some of the clear liquid, mix with equal volume of molybdate solution, let stand for some time at 40°. If precipitate falls return the portion thus tested to the rest; add more molybdate; leave for 12 hours more and test again. When precipitation is complete collect carefully on small filter, washing out the beaker with the filtrate; wash with molybdate solution and water in equal parts, dropped on in small quantities. Dissolve precipitate on filter in ammonia. Add a clear mixture of magnesium sulphate, ammonium chloride and ammonia until its odor is strong; leave for 24 hours, collect precipitate and wash with weak solution of ammonia, (one part of ordinary solution to three of water), until the washings are free from chlorine. Dry, ignite, weigh resulting magnesium pyrophosphate; the weight of which multiplied by 0·4268* is the quantity of phosphoric radical present in the evaporated water.

194. The combined **carbonic acid** is estimated by means of hydrochloric acid of known strength, prepared thus. 100 c. c. of acid are diluted to a litre, and the chlorine in 20 c. c. of the dilution, further diluted with 40 c. c. of water is precipitated by silver nitrate. The chloride is washed carefully by decantation, dried at 175°C. and weighed. The weight multiplied by 0·01272† is the weight of hydrochloric acid in each c. c. of the dilution. To 500 c. c. of the water, evaporated to 100 c. c. (not filtered) and colored with solution of litmus, the dilute acid is added until the color changes to red; the carbonic acid set free is expelled by boiling and more hydrochloric added, if necessary to restore the color. Multiply the number of c. c. of dilute acid used by 0·01272 and the product by 0·822‡; the result will be weight of carbonic acid radical in half a litre.

---

* 222·6 ($Mg_2P_2O_7$) : 95 (PO_4) : : a (weight of pyrophosphate) : x (weight of phosphoric radical); therefore, $x = a \times 0·4268$.

† 143·5 (AgCl) : 36·5 (HCl) : : a (weight of silver chloride) : x (weight of hydrochloric acid in one-fiftieth of original dilution). $\therefore x = a \times 0·25435$ and $50\,x = a \times 12·7175$, and each c. c. contains $a \times 0·01272$ grm.

‡ Each molecule of carbonate (*e.g.*, $CaCO_3$) requires two molecules of HCl to convert to chloride ($CaCl_2$). 73 (2HCl) : 60 (CO_3) : : 1 : 0·822.

195. Having determined as accurately as possible the amounts of basylous and acid radicals in one litre of water, each weight is divided by the chemical equivalent of the substance it represents, in order to ascertain the relative number of atoms and their manner of combination amongst themselves. The attempt is generally first made by supposing the *chlorine* to be combined with the sodium; if the latter is insufficient, with the magnesium; and, if there is still excess, with the calcium. If *sodium* is present in greater quantity than will combine with the chlorine it is calculated with sulphuric acid. This acid (or the remainder of it) is taken as combined with calcium. The rest of the *calcium* and *magnesium* is calculated as carbonates.

196. The **collection** of water for examination requires great care and the duty should never be entrusted to an ordinary servant. The bottles should be cleaned first with a solution of a caustic alkali, next washed with hot water, and then treated with strong sulphuric acid. Before being filled they should be rinsed with the water to be examined. Stoppered bottles are to be preferred; and, if corks are used, they should be new and clean. Taps should be allowed to run for a little time before the sample is taken.

197. The **examination** of water for hygienic purposes admits of division into three degrees of accuracy. The cursory or preliminary examination, which may be made in half an hour, and the materials for which can be kept always at hand, includes the color, taste, odor and clearness of the water; the organic matter estimated by boiling with gold terchloride; the putrescent matter tested by potassium permanganate; the chlorine by silver nitrate; and the calcium by ammonium oxalate. Secondly, what may be termed a qualitative analysis will require at least 24 hours, about four litres of water and certain chemical apparatus. It includes the physical examination; the determination quantitatively of total and volatile solids (132, 133); of oxygen necessary for putrescent and putrescible organic matter (141, 142); of hardness, total, temporary and permanent (173); and of chlorine (155). Calcium and magnesium are precipitated, the carbonates separately (159) (166) from the other salts, and the precipitates compared with those obtained from equal quantities of a known water taken as a standard. Sulphuric acid is similarly estimated (190); and the presence or absence of ammonia (126), nitrates (146) and iron (168) ascertained. Such an examination as this is amply sufficient for hygienic purposes in the great majority of cases,

it needs only simple and inexpensive apparatus (which should be provided at every important station, military or civil,) and it can be made by any ordinary medical officer. Lastly, a complete analysis of water requires the accurate determination of the quantity of each basylous and acidulous radical, of free and albuminoid ammonia, of nitrogen present in nitrites and nitrates, and of oxygen necessary for oxidizable matter. It is highly desirable that our Indian waters should be thus examined with a view to fixing if possible, by comparison of sanitary condition with the composition of drinking water, a standard of purity for the country; but the task demands skilful chemists and costly materials, and is secondary in importance to a less ambitious examination, such as has been indicated above and such as can be made by any sanitary officer.*

198. The means available for the **purification** of water have been, for the most part, already mentioned in connexion with the foreign substances to which they are respectively applicable. It may be well, however, to recapitulate them here and particularize their effects. *Distillation* removes all impurities, except some of the gases, as ammonia. *Boiling* precipitates carbonates held in solution by carbonic acid, expels gases, kills vegetable and animal organisms, breaks up some animal poisons, and probably removes part of the putrescent organic matter. Free *exposure to air* by agitation or by division into narrow streams promotes oxidation of organic matter, removes offensive organic vapors and sulphuretted hydrogen, and increases aëration. *Alum* (six grains to a gallon) or the aluminum sulphate (Bird's Fluid, 20 drops to a gallon) precipitates suspended matters, acting more efficiently in hard waters. *Lime*, in substance or in solution, removes free carbonic acid, thereby precipitating the carbonates which it held in solution and which carry down with them suspended matters. Lime also acts beneficially on dissolved organic impurity. The *permanganates* yield oxygen to

---

* The report on potable waters in use in the office of the Chemical Examiner, Madras, includes:—1, total solids; 2, volatile solids; 3, sodium chloride; 4, total hardness; 5, permanent hardness; 6, free ammonia; 7, albuminoid ammonia; 8, nitric acid; with "remarks" on physical properties, deposits, and animal and vegetable organisms. Nos. 1, 2, 3, are stated in grams per litre; Nos. 4, 5, in degrees of Clark's Scale; Nos. 6, 7, 8, in milligrams per litre.

oxidizable substances of every kind, as putrescent matter and sulphuretted hydrogen. Their good effect is increased (as we have seen) by heat. If the manganic oxide precipitated be considerable, it will carry down suspended matters. The fruit of the *Strychnos potatorum* clears turbid waters, but has no action on dissolved impurities. *Iron*, metallic or oxidized, is supposed to decompose organic matter. *Astringent vegetables*, as kino, bitter almonds, and especially tea, purify water containing organic matters in suspension, as turbid river water. *Charcoal* immersed in fragments or applied by charring the inner surfaces of casks is a powerful purifier of water containing organic matters; but care must be taken to renew its efficacy from time to time by heat or exposure to air, or by recharring the casks. Finally *filtration* may be made to combine the advantages of these methods with benefits peculiar to itself.

199. The effects of **filtration** are threefold. Suspended matters are retained in the interstices of the porous material of which filters are composed; dissolved inorganic matter is similarly, though to a less extent, separated; and oxidizable organic matter, suspended or dissolved, is oxidized, either by oxygen stored in the filtering material or by such substances as alkaline permanganates added to it. On the large scale, the water-supply of towns or extensive buildings is, after the subsidence of the coarser suspended impurities in settling reservoirs, admitted to filtering beds composed of about two feet of sharp sand with three feet of underlying gravel increasing in coarseness towards the bottom.* The rate at which water passes through such a filter depends upon the pressure, and this upon the depth of the water in the bed, which is usually about two feet. In general the discharge may be estimated at 70 gallons in 24 hours for each square foot of filtering surface. Finely divided clay will pass through such a filter, but most suspended matters will be retained. The amount of dissolved mineral matters will be considerably diminished in proportion to the thickness of the layer of sand, which also promotes oxidation of organic impurities. It must be

* Such a filter has been found to lessen impurities to the following extent, expressed in grains per gallon:—total solids, 7·063; volatile solids, 2·360; oxygen required with permanganate, 0·1546 (nearly one-half); chlorine, 0·6; free ammonia, 0·0042; albuminoid, 0·0126.

remembered that the more efficient a filtering bed is, the more rapidly will its interstices become clogged and its power of purification lessoned or destroyed; and especially that dissolved matters at first removed will, at a certain point, begin to be restored to the outflowing water. This should, therefore, be examined from time to time, and the sand removed and cleaned when necessary. It follows that two filtering beds should always be provided, in order to admit of periodical cleansing.

200. Water used for drinking and cooking needs to be further submitted to **domestic** filtration, and various substances are employed as filtering material. All of course are porous and act mechanically; some act chemically besides. Porous sandstone, sponge, flannel or wool may be considered to have only mechanical effect upon the percolating water, though it is possible that, to some slight extent, they promote oxidation also. Charcoal, animal or vegetable, (by itself or mixed with fine sand), hæmatite, magnetic oxide, magnetic carbide, manganic oxide are the principal materials, whose action is chemical: and of these animal charcoal is the best; slow filtration through four inches of which in coarse powder will remove all organic matter. It should be freed from the calcium salts of the bones from which it is prepared, by dilute hydrochloric acid and careful washing, and compressed into small bulk. After being some time in use it must be cleaned by passing solution of potassium permanganate through it, or by free exposure to air. Vegetable and peat charcoal are inferior in purifying power to animal. Next in value is the substance called "magnetic carbide," (prepared by heating hæmatite with saw-dust), which, however, imparts a slightly chalybeate taste to the water; and either is capable of removing a minimum of 40 per cent. of dissolved organic matter, while diminishing nitrites, ammonia and hardness. "Silicated carbon" frees water highly contaminated with organic matter from ammonia, free and albuminoid. As in the case of filter-beds, occasional examination is necessary in order to ascertain whether use is impairing the efficiency of the filter. The filtering substance requires to be cleaned from time to time, either by removal, washing and exposure to air and sun-light or heat, or by passing through it six ounces of a solution of potassium permanganate (20 grains to a quart of distilled water with 10 minims

of sulphuric acid), and subsequently two drams of hydrochloric acid diluted with three gallons of pure water. After about three gallons of distilled or rain water have passed through the filter, it will again be fit for use. Several rough methods of filtration, useful on marches or other journeys, have been suggested. Thus a cask charred inside and having its bottom bored with small holes may be sunk in a turbid stream or tank. Or two casks may be used, one placed inside the other, and the interspace filled with gravel, sand and charcoal; the outer one bored below, the inner having a row of holes near its upper edge. Or a tub with holes at the bottom may have clean chopped straw tightly pressed into it, through which the water rising is filtered.

201. The SOURCES of water-supply are;—Rain collected in tanks or other reservoirs, Wells, Springs, Rivers and Distillation.

202. **Rain** water is wholesome by its purity and agreeable because highly aërated, containing from 3 to 30 c. c. of gas in a litre. The proportion of oxygen in the mixed gases is higher than in atmospheric air, amounting to 32—38 per cent. Carbonic acid contributes 2·5 to 3 per cent. Other substances are met in the atmosphere and dissolved or carried down mechanically. Thus ammonium carbonate and nitrate (the latter more especially during thunderstorms), phosphoric acid, hydrochloric acid (near the sea), sulphuretted hydrogen or soluble sulphides, free ammonia, sodium chloride (sometimes even as much as 2 centigrams in a litre) traces of potassium and calcium chlorides, calcium carbonate (as much as 7 milligrams) and calcium sulphate (as much as 5), may be found in solution in rain water directly collected. Iron, alumina, silica, particles of carbon, light organic substances (as pollen) are found in suspension. Traces of nitrogenous organic matter derived partly from the atmosphere, partly probably from the surface on which the rain falls, are almost always present, and have been known to amount even to 8 milligrams per litre. Silver nitrate turns water, thus containing organic matter, red; metallic silver being precipitated. The total solids of rain water may be taken at a mean of 32 milligrams per litre, the greatest quantity observed having been 0·0509 grm. The impurities of most importance are ammonia, free and albuminoid, and sulphuric acid, the

last being sometimes styled a "measure of the sewage of the air." Free ammonia has been found to range from 0·180 to 9·1 mgrms. per litre; albuminoid from 0·034 to 0·4; sulphuric acid from 2·06 to 70·19.

203. Besides the impurities which rain water derives from the atmosphere through which it passes, it necessarily takes up others, and in larger quantity, from the **receiving surface** on which it falls. When this is a roof—a flat one more especially—dust, organic and inorganic, excreta of birds, bones and feathers, dead insects &c. contribute to the impurity of the supply. When the source of supply is a tank filled by surface drainage, all the impurities of the drainage area will, of course, be liable to be present in the water; and in this case rain water is no purer or better than the water of shallow wells. In the former case the degree of pollution is insignificant, and the probability of the germs or poisons of specific diseases finding their way into the system through the drinking water is reduced almost to a minimum. It is desirable, therefore, that this source of water-supply should be taken advantage of as much as possible, and that means should be adopted for the collection of all rain falling on the roofs of barracks, jails and other large buildings. Filtration through an oxidizing medium is still necessary before use.

204. Knowing the annual rainfall at any place and the area of the collecting surface, the **quantity** of water obtainable from rain is calculated. The area in square feet multiplied by 144 is the area in square inches, the product of which by the rainfall in inches is the number of *cubic inches* of rain falling upon the given surface in a year. This figure multiplied by 0·00361 gives the quantity in *gallons*.* If the receiving surface is a sloping roof, the area is the space covered by it, *i.e.*, the area of the building measured outside, and allowing for any additional surface afforded by projecting eaves. For a roof surface the calculation of rain-supply is easy, because the whole can be collected; but of the rain which falls upon the ground, some sinks and some evaporates; the proportion thus lost varying with soil and climate from one-half to seven-eighths.

---

* There are 1,728 cubic inches in 6·2355 gallons of pure water at 15°5. $6·2355 \div 1,728 = 0·003609$. One inch of rain on a square yard gives 4·679 gallons, because $9 \times 144 \times 0.00361 = 4·67856$.

205. The supply should be estimated at the average, or at the minimum, rainfall of as many years as possible at the place itself. Observations made at a distance of even a few miles may be worthless as the foundation of an estimate.

206. The composition of **well water** depends upon the strata through which a well is sunk, the condition of the neighbouring surface and the measures taken to preserve the water from contamination. That portion of the rain which sinks into the ground percolates into wells, dissolving the soluble matters with which it meets in its course, aided, as we have seen, by carbonic acid derived from the soil. The space thus drained by any well, and consequently the supply of impurities on which it draws, varies with its depth and the nature of the soil. Thus if the soil is very loose a well of 80 to 100 feet in depth may drain a cone whose apex is at the bottom of the well, and whose base is a circle of 50 feet radius. A well may be considered secure from pollution situated external to a cone of half a mile radius, whatever be its depth or the looseness of its soil; but it is not possible to lay down precise rules on this point. Sea-water will penetrate through considerable distances unless impermeable clay or rock protect the well. Cess-pools, sewers, pools of stagnant water may contaminate wells with organic matters in solution and even in suspension, if situated within the drainage-cone. So also excrementitious and other refuse substances lying on the surface of the ground will contribute organic impurities to the soil and thence to the well water. It is true that the soil at first acts powerfully as a filter, intercepting most of the suspended impurities and those most likely to be injurious to health; but the purifying effect necessarily diminishes in time, and may even be reversed when the soil becomes saturated with filth carried in from the surface by percolating water.

207. Besides the impurities to which the water of wells is liable, derived through the soil in which they are sunk, they may receive foreign substances **directly** through their mouths. Surface floods may wash into them every kind of impurity, organic and inorganic; animals may fall in; persons suffering from painful diseases not unfrequently choose throwing themselves into a well as a convenient mode of suicide; the wind will blow in dust, leaves &c.;

foul vessels will be used for drawing water; dirty people may wash themselves at the edge.

208. The **purity** and wholesomeness of well water depend, therefore, on the position and protection of the well. Wells sunk in granite, metamorphic rock or basalt generally yield pure water; in most cases, however, sand, gravel or alluvium is the material through which the water percolates; the last of which is the least desirable. Choice of soil in which to dig a well is rarely afforded, and, in general, it is only possible to preserve wells already existing from avoidable pollution and to select for use those which are free from obvious external sources of impurity. Thus the neighborhood of burial-grounds, cess-pools, sewers or ill-constructed surface-drains, nullahs (invariably used as latrines), tanneries and slaughter-houses, unclean dwellings, stagnant surface pools or tanks in which human beings or animals habitually bathe or clothes are washed, fields which are freely manured, should be avoided in choosing a well for domestic use. The surface around, within the drainage area, should be kept free from animal and vegetable refuse, and should be carefully drained, so as to afford no lodgment to water. The mouth of the well should be protected by a parapet, and an impermeable platform sloping from its base and provided with a drain, so that spilled water may not return to the well. Should cattle be used for drawing the water, the path in which they travel must be drained and kept clean. The well should be covered with a shed as low as is compatible with convenience in drawing water, and the aperture should be restricted by the same limit; indeed, it is desirable that wells of average depth should be completely covered in and their water drawn by a pump. When a bucket is used, wood or galvanized iron is preferable to leather; and no private vessel should be employed, because there can be no security for its freedom from dirt, and it is at least possible that cholera and other diseases are thus disseminated. The vessel for general use should be examined frequently, and cleaned when necessary. Lastly, a well which has been long disused should, if required for use, be emptied, cleaned, allowed to refill, and the fresh water left long enough to deposit suspended matters.

209. The **quantity** of water which a well may be expected to supply at any given season is ascertained by emptying

it completely or partially, measuring the water withdrawn and observing the time required for its replacement. From these two data the yield in 24 hours is easily calculated. If a cask be used for measurement, its contents in gallons may be estimated as $= 26\,(h^2.25 + b^2.39 + bh.26) \times 0{\cdot}0000314 73 l$: where $h =$ least and $b =$ greatest width, and $l =$ length, in *inches*. Should the only available measure be a part of a cask or a tub, the contents in gallons of each 10 inches are the quotient of the square of the mean diameter of those 10 inches by 3530·4. The mean diameter of the lowest 10 inches (for example) will be half the sum of the diameters at 5 and at 15 inches from the bottom. These methods are only approximative but rigid accuracy is obviously unnecessary in the case. It is scarcely necessary to add that the estimate is valuable only for the particular season at which it was made; most wells diminishing their yield and some failing altogether in the rainless months.

210. **Springs** are supplied immediately by subterraneous reservoirs which are themselves dependent upon the rain percolating through the strata overlying and surrounding them. The water which they yield is liable to the same kind of impurities as that of wells, though generally in a less degree; and most of the precautions and protection which the latter require are in many cases applicable to springs. From the time which is required for filling a vessel of known capacity from a spring its yield is calculated. The yield of a spring or of a small stream often varies at different hours of the day; and determinations should, therefore, be made at several different times. The probability of permanence is a question of great importance on which a geological examination of the country will sometimes throw light. Springs rising at the foot of hills will probably yield a continuous supply. In plains they will generally fail in the dry months. In limestone districts natural reservoirs are formed by solution of the rock, which hold large quantities of water and supply perennial springs. Large masses of very permeable sandstone or other rock sometimes yield permanent springs and streams to districts on a lower level.

211. **A stream** or small river occasionally supplies water to a town or camp. In addition to the ordinary impurities of the springs which flow into it a stream is liable to pollu-

tion by surface drainage, dead organic matter, fæcal impurities washed in by floods, and suspended clay &c. from the same source. The supply is precarious, the smaller streams, as a rule, drying up in the hot season (though water may always be found by digging in their beds). The beds when thus dry are liable to much pollution with organic and noxious material, which subsequently is taken up by the water. It is obvious, therefore, that a stream, especially if villages are situated on its banks above the position, is in general a most objectionable source of water-supply, and one indicating careful filtration or boiling as essential.* It occasionally happens that troops marching through an uninhabited or thinly-peopled country may find in a stream a convenient and wholesome supply. In such a case precautions should be taken to preserve it from being fouled by the cattle of the camp or by washing clothes or persons in it at any points above the most convenient part for obtaining water for drinking and cooking. The spot best suited for this purpose having been selected, another for watering cattle, lower down the stream, should be chosen, and a third, below this, for washing of every kind.

212. It is sometimes useful to ascertain the **quantity** of water which a small stream may be depended on to supply. This is calculated in the following manner:—Choose or make a straight length of as many feet as possible in the course of the stream. If the breadth and depth of this part of the channel are not uniform, measure them in several different places and take the mean of the products for the sectional area (a). Mark with two stones a distance of 150 to 200 feet at least, and note the time which a piece of wood about 4 inches square and ¾ inch thick, put into the middle of the stream above the upper mark, takes to reach the lower one. This observation gives the surface velocity; and this, multiplied by 0·8 (for small streams, 0·9 for rivers), is the mean velocity (V). Then $D = a\ V$, D being the discharge of water sought.† It may be more convenient to calculate by means of a **sluice-gate** through which the stream is made to pass. Here $D = a\ 5\ \sqrt{h}$; a being the area of the opening through which the water passes, and h the height of the water level above the sluice from the centre of the aperture.

213. Many populations are dependent upon **rivers** for their water-supply. In this country the periodical rains and

---

* Water from jungle streams, though clear and apparently pure, is often the vehicle of malaria.

† For example, let surface velocity be 50 feet per minute. $V = 50 \times 0{\cdot}8 = 40$ feet per minute. Let mean depth be 1·5 foot, mean breadth 2 feet; mean sectional area $= 3$ feet. $D = 40 \times 3 = 120$ cubic feet per minute, which, multiplied by $6{\cdot}23 = 747{\cdot}6$ gallons per minute.

the habits of the people often render this source of supply highly unsatisfactory. In time of flood rivers bring down suspended clay, sand &c. in large quantities, besides the washings of their beds, fouled with every impurity during the dry season, and of the nullahs which open into them. Dead bodies are often thrown into rivers, and the sewage of towns and drainage from tanneries, slaughter-houses, dye-works &c. are conducted into them. On the other hand the impurities are largely diluted, while the continual exposure of fresh surfaces to the air promotes the oxidation of putrescent organic matter and the deposition of carbonates held in solution by carbonic acid. It is evident that water taken directly from rivers, especially in time of flood, should be carefully filtered before use; or, if this be impracticable, it should be boiled either by itself or with tea leaves.

214. Not only the quantity of the water derived from the sources already considered, but also its quality, varies widely with the season, and this point has to be considered in judging of the fitness of a tank, well, spring, stream or river for supplying particular wants. In dry weather evaporation concentrates water, increasing the proportion of solid impurities, and the accompanying heat favors putrefaction of organic matters. Inquiries should always be instituted as to the *permanence* of a source of water-supply; analyses should, if possible, be made at two or three different periods in the year, and if one only can be made, the season and its probable effect upon the water should be considered and allowed for.

215. At sea and in coast towns where the rainfall is scanty and precarious, (as at Aden), distilled water is often used. Steam vessels generally carry apparatus for the distillation of sea water or for condensing steam from their engine-boilers; but in case of failure of fresh water on board a sailing vessel any means of heating salt water and condensing the vapor will afford a supply. The steam may be collected on a metallic surface, or on an earthen dish, changed when it becomes heated; or may be received in a clean woollen cloth, wrung out from time to time as it becomes saturated. Water thus obtained is insipid and perhaps indigestible, owing to absence of aëration. This disadvantage is obviated by exposing it to air in divided streams. It may contain sodium chloride, but not to any

considerable degree. Magnesium chloride volatilized and decomposed may contribute hydrochloric acid, which should be neutralized by a little sodium carbonate.

216. The QUANTITY of water necessary, directly or indirectly, to health is next to be considered under the heads of *food*, *washing* and *sewerage*. This division is convenient, because different qualities of water are applicable to the different uses. It is, of course, desirable that the supply should be unlimited, but this is in many cases impossible and the minima compatible with health should be known. The manner in which the supply is obtained has a great effect upon the quantity used. If water has to be drawn from deep wells or even pumped up by members of the household, much less will be considered necessary for health and comfort. If the supply is constant and requires only the turning of a tap, there will be great waste, and the quantity consumed will far exceed the quantity really required. Except on boardship it rarely happens that an attempt is made to distribute to each individual or to each family the theoretical ration.

217. The water required for food is partly drunk and partly used for cooking. Under ordinary circumstances of temperature and exertion 0·4 gallon will be sufficient for the former purpose for a man in 24 hours. More will be required if the heat is great, or the exertion undergone severe. As women and children drink absolutely less than men, this allowance will be sufficient when supplied for each of the residents of a barrack, jail or town, or the members of a household of average composition. For cooking 0·6 gallon will generally be a sufficient allowance, making the total for food one gallon daily for each individual, and this is the quantity found necessary on boardship in the tropical seas. As a general rule, the same water will be supplied for the two food purposes, but a difference may sometimes be compulsory. In this case it is to be remembered that saline waters unfit to drink may be freely used for cooking; and, on the other hand, that water of considerable temporary hardness may be palatable and wholesome to drink but unsuited to culinary use.

218. Provision has to be made for cattle also, both for their drink and for the preparation of their food. The quantity required for the former will vary, as in the case of men, with temperature and work; but the following

numbers may be taken as applicable to ordinary circumstances in this country :—

Horse	8	gallons.
Bullock or cow	8	do.
Mule	6	do.
Pony	6	do.
Elephant	30	do.
Camel	12	do.
Sheep	1	do.
Pig	1	do.

219. Unless water of the best quality is scarce, it should be supplied to cattle for their drink. When they are fed on *chenna* which requires only steeping in cold water for its preparation, or when *khulti* is used without boiling, a gallon of water may be allowed for four "measures" of the food; when boiling is considered necessary, the allowance should be two gallons. As regards the quality of the water used for this purpose, the same remarks apply as in the case of preparing human food.

220. **Washing** of persons and cattle, clothing, houses, furniture and utensils is of very great importance to health, and ample provision should be made for it. For **bathing** the quantity needed varies considerably, a bath-tub requiring at least 30 gallons for comfort and often containing more than 50, while 12 gallons poured over the body from chatties affords a bath considered amply sufficient by many persons, and 4 gallons are enough for a sponge-bath. A plunge-bath measuring 20 feet by 12 by 5 holds 7,500 gallons of water, and if supplied continuously, so that it should receive in two, or even in three days that amount of fresh water (entering above at one end and issuing below at the other), will provide ample means of ablution for a regiment, or the inmates of a large jail. In this country, where a complete bath daily is habitually taken and is necessary to health, provision for minor ablutions may be considered as included in the estimate for baths. The quality of bath water is comparatively of little importance. It should not be muddy; and if it is too salt or too hard soap will be wasted. Water from stagnant and muddy tanks may contain the ova of guinea-worms. In some rare cases, water produces urticaria or other cutaneous eruptions, but they are exceptional and need no further notice.

221. If it be necessary to make provision for the washing of **other animals** (to whose health and efficiency a clean skin is scarcely less essential than it is to their owners') two gallons should be allowed for a horse, bullock, cow or buffalo, and corresponding quantities for others in proportion to their size.

222. The customs of the country relieve us from the necessity of providing water for the washing of **clothing**, for which dhobies may invariably be trusted to make their own arrangements. As regards **dwellings**, floors of earth or plaster will not admit of washing; and walls, unless finished with polished chunam, are cleaned by sweeping or by a fresh coat of lime-wash. An allowance of two gallons per head will be ample for the maintenance of houses, jails or barracks in a state of proper cleanliness. For utensils three gallons will be sufficient.

223. It is apparent from the foregoing paragraphs that the **total** quantity of water necessary for a community varies within very wide limits according to circumstances. It is useless, therefore, to attempt to lay down precisely any general rule. The figures given above afford the means of estimating total requirements in any particular case. The minimum under ordinary circumstances may be taken at 12 gallons daily per head for personal and domestic use, without baths; with baths and perfect cleanliness in other respects, 16 gallons, with no waste or expenditure in water-closets or latrines. When the supply is very small the minimum should never fall below 4 gallons per head.*

224. Hitherto the wants of persons in ordinary health have been considered. **Hospitals** require a much more copious water-supply, in proportion to their number of inmates, than other dwellings. More water is drunk, more liquid food is consumed, baths are more frequent and more abundant, the boiling of clothing and bedding before sending them to be washed is often desirable, extreme cleanliness of floors, walls, cots and utensils of all kinds is essential, irrigation and washing of wounds, bruises &c. consume a large amount of water. The supply to a hospital, therefore, should, if possible, be unlimited and waste is a less evil

---

* The War Office allowance is 15 gallons daily for each *man* with no extra supply for women or children.

than even trifling deficiency. Should the total supply be limited, economy should be practised at the expense of the healthy, and the hospital amply provided. If it should be necessary to make an estimate for hospital use, 30 gallons per head will not be excessive for drinking, cooking, bathing and washing.

225. The quantity of water which should daily pass through **sewers**, in order to maintain their cleanliness, cannot be fixed: so much depends on their fall and shape and on the materials which are permitted to enter them. When solid and liquid excreta have to be removed by them, a minimum of 25 gallons per head daily (besides rain) has been laid down; but this is a case with which we are not likely to be called upon to deal. As a rule, our sewers will contain only the liquid refuse of the cook-rooms, the washings of houses and utensils, and the water which has been used for bathing; and the last will generally be sufficient, with ordinarily well-constructed sewerage, to dilute and remove the others. Sewers will require watching to ensure their freedom from obstruction and from consequent generation of noxious or unpleasant gases; and flushing copiously with water of any kind will be the remedy, when they become foul. The best test of the satisfactory state of sewers is not the quantity of liquid which they receive, but the quality of the discharge at their out-fall. When this is scanty, semi-solid or offensive, free flushing is indicated.

226. The effects of **insufficient supply** of water are closely connected with those of impure supply, and also with those of a polluted atmosphere. Absolute privation of water for drinking needs not be considered here; partial privation is productive of so much inconvenience or suffering that any kind of water will be drunk—even from the foulest pools—to satisfy thirst. Not only, however, does this indirect evil consequence follow from want of drink, but also great muscular debility, with disinclination to, and incapacity for, exertion result. It follows that a constant supply of the best drinking-water available is essential to the efficient performance of labor of every kind, and that for soldiers on march or in action, for coolies at work, or for prisoners undergoing really hard labor, water should always be at hand to compensate the loss by lungs and skin. Water should be, under such circumstances, not procurable merely, but obtainable conveniently

at any moment, so that the needful supply may be taken in small quantities from time to time, not in copious draughts at once. When water for cooking is insufficient, the processes necessary to the digestibility of food will be unsatisfactorily performed; or the same water used more than once will be more liable to putrefactive changes and consequently more likely to act injuriously both through stomach and lungs than if it were used once only and then removed. It is unnecessary to dwell upon the necessity of cleanliness to health. Insufficiency of water for personal ablution is incompatible with the due action of the skin which, in hot climates more especially, is of vital importance, and skin diseases as well as a generally depressed state of health will inevitably follow; while the atmosphere is polluted by effluvia, in great part organic, from unwashed or imperfectly washed clothes, furniture and utensils. Lastly, if the water-supply is insufficient for other purposes, it must be altogether inadequate to the free removal of refuse by the sewers. If these are intended to convey not only water which has been used but also excreta, the propagation of enteric fever, cholera and other diseases, and possibly the origination of the first and others, will be favored by the clogging of the sewers and the drying of their contents. In ordinary cases the air will be poisoned by noxious gases and organic effluvia generated in uncleared sewers.

227. In the great majority of cases the water-supply is derived from wells, of which as regards STORAGE nothing need be said. Sometimes open *tanks*, supplied by rainfall or surface-drainage or from rivers, yield the necessary supply. In this case the drainage area must be kept as clean as possible; washing of any kind should not be permitted in water intended for domestic use; dead animals and plants should be removed, while the presence of living fishes, molluscs and vegetation, in moderate amount, should be encouraged. The walls should be of clay or rock or dry masonry; or, if mortar be necessary, it should be hydraulic, so as to give no lime to the water. Evaporation at a given temperature being rapid in proportion to surface, this should be as small and depth as great as possible.* In places where the annual rainfall is low,

* Loss by evaporation has been known to amount in Calcutta to $2\frac{1}{2}$ inches in 24 hours.

and consequently water is scarce, subterranean reservoirs may with great advantage be constructed for the storage of rain water falling on the roofs of large buildings. Such receptacles should be built of stone or well-burnt brick, set in hydraulic mortar and lined with portland or other suitable cement; they should be dark, but well-ventilated, deep rather than wide, and capacious in proportion to the maximum rainfall. There should be no possibility of pollution by percolation from drain, sewer or cess-pool. The rain should not enter directly from the roof, but should be received in a shallow, carefully lined well, having two or three feet of sand and gravel through which the water passes on its way to the reservoir; and a second filtration by ascent may beneficially be interposed before the latter is reached. The filtering-well should be covered in; and the filters renewed before the setting in of each rainy season. Finally, whenever a reservoir becomes empty, it should be thoroughly cleansed. *Cisterns* are used with great advantage for storing smaller quantities of water for domestic use. These are best made of good zinc or galvanized iron, it being remembered that zinc not unfrequently contains lead.* Lead itself is often used for this purpose; and the conditions under which no harm may be expected to result have been already considered (185). Cisterns should be emptied periodically and carefully cleansed; they should be covered in, and the pipe which conveys away overflowing water from them should never pass into a sewer or closed drain, lest offensive gases should ascend and be absorbed by the water); but it should terminate either in an open surface-drain or at some distance above the opening of a covered passage. As to the *sufficiency* and *strength* of a tank or other reservoir, its capacity in cubic feet, multiplied by 6·23, gives its contents in gallons; and the weight of a cubic foot of water, and, therefore, its pressure on a square foot of surface, may be taken as 62 lbs.

228. The DISTRIBUTION of water is perfect when every house and every storey of a house has a constant supply sufficient for every want. In hospitals such a state of

* Water containing chlorides acts on zinc itself, and the resulting salt is not precipitated by boiling. Oil-paint prepared with ochre or asphalt, instead of lead, will protect from this action.

things should invariably exist; in other cases more can rarely be expected than that the needful quantity of water shall be obtainable without such labor or inconvenience as may diminish consumption. In villages, wells of 15 to 30 feet in depth generally abound, from which the women of the poorer classes and the servants of the wealthier readily draw sufficient water for household requirements. In large towns the supply is often scantier and obtainable with greater difficulty; but municipalities will probably in such cases take measures to bring water from a distance by closed or open aqueducts within easy reach of every house and available at all times, the last condition being indispensable in a tropical climate. Barracks should have a constant supply in or near every building, in spite of the inevitable waste which the carelessness of the soldier and of his attendants will be sure to cause. Water should be raised by force-pumps from wells or reservoirs, every morning or evening, to cisterns on the top of each building, capable of holding 24 hours' supply In jails there appears to be no reason why the treadmill should not be substituted for the nominal "hard labor" of the present day and the force thus obtained applied to raising water for all purposes to elevated cisterns. On the line of march and in action, the services of the *puckally* and the *bheesty* will always be required, and it will be long before they can be dispensed with in the hospital and the barrack.* Their water-vessels should be carefully examined at short intervals.

229. Aqueducts conveying water from a distance for the supply of towns should invariably be covered in along their entire course. Arched conduits carefully constructed and lined with hydraulic cement will be most suitable for this purpose on the large scale; but in most cases iron tubing will be the most convenient material. For subordinate distribution also, iron pipes are, on the whole, the best adapted: lead and zinc may sometimes be used with safety, but they are better avoided.† When pressure from

* The water-load of the former is about 27 gallons, of the latter 9.

† Several patents for utilizing lead in the distribution of water have been taken out. In Haines', block-tin pipes are enclosed in leaden; in McDougall's, the lead is coated with bitumen; in Schwartz's the lead is coated with lead sulphide by boiling the pipes for fifteen minutes in a solution of sodium sulphide.

within or from without is not considerable and danger of accidental fracture from other causes is absent, pipes of glazed earthenware carefully joined are well suited to the conveyance of water. The fall should not be less than 1 in 1,000; nor more than 1 in 300, unless the pipes are cast-iron. Socket-joints are best, although they are liable to leakage through changes of temperature. For the same reason lead should not be used for closing the joints (because the rates of expansion of it and of iron do not correspond) where the range of temperature is considerable.

230. The indications of the presence of water and the SEARCH for it may not improbably be points of great importance to exploring or survey parties, to troops marching in an unknown country or to officers selecting a site for a camp or a station. In the first place, wells should be sunk in permeable strata only, unless geological examination of the country has shown that impermeable rocks overlie permeable, and that the latter crop out, so as to receive the rainfall or water from other sources. On this principle, on the large scale, artesian wells are sunk to enormous depths through impermeable rocks into underlying permeable and water-bearing strata. Secondly, rivers apparently dry flow subterraneously and water will almost always be found by digging in their beds. Similarly, the dry courses of nullahs are promising sites for wells, and more especially at the point where two unite. Thirdly, greater abundance or verdure of vegetation often indicates closer proximity of water to the surface: and where there is no vegetation, as on a sandy plain, fogs in the early morning give reason to expect water at no great distance below. Fourthly, amongst hills the lowest convenient part of a valley should be chosen; and a spot which is nearer to the higher bounding hill: and the junction of two valleys will be preferred. Lastly, on the coast, the immediate neighbourhood of the sea should be avoided, unless an impermeable barrier of clay or rock prevent the percolation of salt water.

CHAPTER IV.

FOOD.

231. Every action of an animal's body or mind involves disorganization of tissue. The waste arising from this cause and from the maintenance of the temperature of the body at the standard of health, by processes of combustion on the one hand and by evaporation from the surface on the other, must be compensated by FOOD. Food, therefore, includes all substances capable of replacing wasted tissue, of preventing or retarding waste or of aiding indirectly in the processes of repair. The conditions essential to the hygienic suitability of food are (1) that it should contain all the elementary substances which the body itself includes, (2) that these should be combined into certain forms which experience has shown to be necessary to efficient nutrition, (3) that the total quantity should be sufficient for the wants of the body, according to varying circumstances of exertion, climate &c., (4) that the classes into which science and experience have taught us to divide aliments should be present in certain definite proportions to each other, (5) that the articles of food should be of such a nature and in such a state as to be suited to the digestive powers of the man or other animal to be fed, and (6) that the food or its mode of preparation or both should be so varied as to ensure sufficient ingestion and effective assimilation.

232. The important **elements** which enter into the composition of the animal body are :—the organic group, nitrogen, carbon, oxygen and hydrogen; potassium and sodium, calcium and magnesium, iron, chlorine, phosphorus and sulphur.

233. It is unnecessary to consider **oxygen** and **hydrogen** in detail, as provision for the due supply of the other two organic elements will imply the presence of the former in sufficient quantity. Both are present in all foods derived from the animal and vegetable kingdoms, and in water.

234. **Nitrogen** enters into the composition of all structures of the body concerned in the generation of any kind of force; it is, therefore, essential to the repair of nerves, muscles, glands &c. The bile and other digestive fluids contain it, so that for their maintenance also it must be supplied. The nitrogenous structures control the absorption of oxygen, its condensation, its application to the oxidations necessary to life. The activity of these processes is proportional to the size and vigor of the nitrogenous organs; without which no oxidation or production of energy would be possible. Reduction of supply of nitrogen below a certain point inevitably leads, more or less rapidly in proportion to degree of diminution and amount of reserve of nitrogen in the body, to imperfect performance of the functions, to disease and decay. Increased energy of function demands increased supply of nitrogen. This element, therefore, is an essential constituent of the food of the higher animals, and, as we shall see, its presence or absence is a most important point in the classification of aliments.

235. Many physiologists have attempted to determine by observation and experiment the **quantity** of nitrogen necessary to health in different circumstances. The results agree as closely as could have been expected, considering the complexity of the problem; and the following numbers may be taken as sufficiently accurate for practical purposes. The unavoidable internal work of the body of an adult human being, that is, the movements necessary for respiration, circulation and digestion, require a minimum of 138 grains of nitrogen in 24 hours for their maintenance. In a state of idleness of mind and body the least amount compatible with health may be stated as 200 grains for a man and 180 for a woman; anything below these quantities being 'starvation,' especially if any work is to be done.* In the ordinary circumstances of the soldier, the artisan, the field-laborer and the prisoner in most of our jails, 300 grains will be a fair minimum. Very great physical exertion will demand 500 grains and even more. The dietary of a prize-fighter under training was found to include in one instance 690 grains of nitrogen.

* The "Temple ration" for laborers on relief-works was based on one pound of rice, containing 68 grains of nitrogen.

236. Nitrogen is supplied by a very large number of alimentary substances, containing it in very various proportions. One group of these, including the various forms of albumen, syntonin, fibrin, casein, legumin and several other bodies, classed together as "albuminates," correspond very closely in composition and principally supply the quantity of nitrogen required. Of these albumen contains 15·6* per cent. of nitrogen, and 15·8 may be taken as the average proportion for anhydrous albuminates. Hence one ounce of any of these aliments is estimated to contain 69 grains of nitrogen,† and the weight of albuminate in any food multiplied by 0·158 expresses the weight of nitrogen.‡

237. The following table gives the quantity of nitrogen, in grains, contained in one pound of the principal nitrogenous foods :—

Bacon, dry	95	Fish, white	195
„ green	76	Herrings, red	217
Barley-meal	68	Maize-meal	120
„ pearl	91	Malt liquor	1
Beef, best steak	227	Milk, new	44
„ cooked	304	„ skimmed	43
„ fat, uncooked	154	Mutton, best chops	227
„ ordinary „	184	„ cooked	304
Biscuit	363	„ uncooked	189
Bread, average	88	Oatmeal	136
„ crumb	58	Parsnips	12
„ crust	76	Pease (split)	248
Bullock's liver	204	Pork (fat)	106
Butter	0·2	Potatoes	22
Butter-milk	44	Rice	68
Carrots	14	Sago	13
Cheese, Cheddar	306	Turnips	13
„ skim-milk	483	Vegetables (green)	14
Cocoa	140	Wheat-flour (seconds)	116
Egg	149	Whey	13

* The empirical formula of albumen is $C_{72}H_{112}N_{18}SO_{22}$; and 1,612 : 252 ($N_{18}$) :: 100 : 15·6.

† 100 : 15·8 :: 437·5 grs. : 69·125 grs.

‡ An albuminate containing 15·8 per cent. of nitrogen, any aliment including x weight of albuminates will have $x \times 15{\cdot}8 \div 100 = x \times 0{\cdot}158$ weight of nitrogen.

238. Taking 300 grains of nitrogen as the standard amount required daily under circumstances of ordinary labor, the following table shows the quantity, in *ounces*, of various foods capable of supplying it.

Bacon	50·5	Milk, new	108·6
Barley-meal	70·6	,, skimmed	111·3
Bread	55·0	Oatmeal	35·4
Cheese (skim-milk) ..	9·9	Pease	16·8
Fish (white)	24·6	Rice	70·6
Maize-meal	40·2	Wheat-flour	41·2
Meat (lean)	23·4		

239. In these tables the substances have been considered as being in their ordinary condition and containing a considerable quantity of water. In the following a comparative view of the proportion of nitrogen in some ordinary foods **free from water** is presented, the amount in human milk being taken as 100.

Vegetable.		Animal.	
Rice	81	Yolk of egg	305
Potato	84	Oysters	305
Maize	100	Cheese	331
Radish	106	Bullock's liver	570
Wheat	106	Pigeon	756
Barley	125	Mutton	773
Oats	138	Salmon	776
White bread	142	Lamb	833
Black ,, ...	166	White of egg	845
Pease	239	Lobster	859
Lentils	276	Veal	873
Haricots	283	Beef	880
Beans	32C	Pork	893
Cow's milk	237	Ham	910

240. **Carbon** is a constituent of every tissue of the body, and of every secretion except a few consisting of water and salts. Its oxidation is the principal source of animal heat and energy. Food, therefore, must supply it in abundance and all alimentary substances derived from the organic kingdoms contain it. The quantity necessary for the support of an average adult in a state of rest, for 24 hours, may be stated as 3,500 grains or 8 ounces. 5,000 grains (11·4 oz.) may be safely taken as a maximum, under any circumstances of exertion, though higher

numbers are given by some authors.* Generally speaking, about five-sixths of the necessary carbon is supplied by non-nitrogenous foods, one-sixth by nitrogenous.

241. In the following table the carbon included in one pound of various foods is given in grains. The table contains the nitrogenous substances previously given (237) and also others into the composition of which nitrogen does not enter.

Bacon, dry	5,987	Herrings (red)	1,435
,, green	5,426	Lard	4,819
Barley-meal	2,563	Maize-meal	3,016
,, pearl	2,660	Malt liquor	274
Beef, cooked	1,854	Milk, new	599
,, fat, uncooked ..	1,573	,, skimmed	438
,, ordinary ,, ..	1,024	Mutton, cooked	1,883
Bread	1,975	Oatmeal	2,831
Biscuit	2,928	Parsnips	554
Bullock's liver	934	Pease (split)	2,699
Butter, fresh	6,456	Pork (fat)	4,113
,, salt	4,585	Potatoes	769
Butter-milk	387	Rice	2,732
Carrots	508	Sago	2,555
Cheese, Cheddar ..	3,344	Suet	4,710
,, skim-milk ..	1,947	Sugar	2,955
Cocoa	3,934	Turnips	263
Dripping	5,456	Vegetables (green) ..	420
Egg	1,144	Wheat-flour (seconds) ..	2,700
Fish, white	871	Whey	154

242. The following table shows the number of grains of carbon contained in such quantities of certain nitrogenous foods as are capable of supplying 300 grains of nitrogen:—

Bacon	18,925	Milk, new	3,957
Barley-meal	11,995	,, skimmed ..	3,073
Bread	6,798	*Oatmeal*	6,276
Cheese, skim-milk ..	1,167	Pease	3,246
Fish (white)	1,254	*Rice*	12,079
Maize-meal	7,569	*Wheat-flour*	6,970
Meat (lean)	1,426		

Those foods whose names are printed in italics contain, it will be observed, an amount of carbon exceeding the maximum.

* Dr. E. Smith states that 7·9 oz. of carbon are given off from the body of an adult man in 24 hours, in a state of rest, 9·5 oz. under light exertion, 12·5 oz. when the work is hard; and so demands for his average man 9·5, 10·5 and from 12·5 to 14 ounces of carbon, under these different conditions.

243. Carbon is taken into the body in five different states of combination. It forms part of albuminates, of fats, of starches, of sugars and of certain salts, chiefly of vegetable origin, which are capable of conversion into carbonates in the system. These last may be disregarded here; the carbon of the others can be easily estimated. Thus, albuminates contain on the average 53·5* per cent. of carbon. Therefore the weight of albuminate in any given quantity of food multiplied by 0·535 gives the weight of carbon. Fat contains 79† per cent. of carbon, and the corresponding multiplier is 0·79. Starch contains 44·4‡ and the multiplier in 0·444; cane-sugar and lactose or milk-sugar, 42·1§, giving 0·421; grape-sugar, 40·0 and 0·4.‖. From these numbers we find also that one ounce of albuminate contains 234 grains of carbon; of fat 346 grains; of starch 194 grains; of sucrose 184 grains; and of glucose 175 grains.

244. It is sometimes convenient to estimate the carbon contained in the non-nitrogenous part of food under the one head of starch instead of under two or more divisions. This is done by assuming that the dietetic value of the carbonaceous foods depends upon the quantity of oxygen with which their carbon and hydrogen must combine in order to form carbonic acid and water. Estimated thus, fat is 2·4¶ times as powerful as starch, and, therefore, the weight of fat in the food multiplied by 2·4 is added to the weight of starch actually present. In the following table the carbonaceous principles are thus grouped together, estimated as if they were all starch :—

* 1612 (*albumen*) : 864 (C_{72}) :: 100 : 53·6.

† The analysis of human fat yields 79·000 per cent. of carbon; of lard 79·098; of mutton fat 78·996. Calculation from the formulæ of stearine, margarine, and oleine, gives 76·9, 76·4 and 77·3 per cent. respectively.

‡ 162 (*starch*, $C_6H_{10}O_5$) : 72 (C_6) :: 100 : 44·4.

§ 342 (*sucrose*, $C_{12}H_{22}O_{11}$) : 144 (C_{12}) :: 100 : 42·1.

‖ 180 (*glucose*, $C_6H_{12}O_6$) : 72 (C_6) :: 100 : 40.

¶ Fat requires 298·7 weights of oxygen for the oxidation of its carbon and hydrogen, of which itself contains 10; starch requires only 118·5 having in itself sufficient oxygen for its hydrogen. The ratio of 288·7 to 118·5 is 2·4 : 1. The percentage composition of fat is taken as C79, H11, O10; of starch C44·44, H6·17, O49·39.

Foods.	Nitrogenous aliment per cent.	Carbonaceous aliment (reckoned as *starch*) per cent.
Arrowroot	...	82·00
Bacon, dried	8·8	183·25
„ green	7·1	167·00
Barley-meal	6·3	80·30
Bread	8·1	55·00
Beef, fat	14·8	74·50
„ lean	19·3	9·00
Butter and fats	...	207·50
Butter-milk	4·1	8·15
Carrots	1·3	15·00
Cream	3·7	69·55
Cheese, Cheddar	28·4	77·75
„ skim-milk	44·8	15·75
Egg, entire	14·0	26·25
„ white	20·4	...
„ yolk	16·0	76·75
Flour, wheaten	10·8	75·50
Liver, ox	18·9	10·25
Maize-meal	11·1	85·35
Milk, new	4·1	14·95
„ skimmed	4·0	9·90
Mutton, fat	12·4	77·75
„ lean	18·3	12·25
Malt liquor	0·1	8·70
Oatmeal	12·6	77·80
Pease	23·0	62·65
Potatoes	1·0	22·50
Parsnips	1·1	16·65
Pork, fat	9·8	122·25
Poultry	21·0	9·50
Rice	6·3	81·25
Sugar*	...	95·00
Salmon	16·1	13·75
Turnips	1·2	7·20
Treacle	...	77·00
Tripe	13·2	41·00
Veal	16·5	39·50

To find, for instance, the percentage of nitrogen in pease multiply 23·0 by 0·158 (236). The product, 3·63, is nitrogen per cent. So also 23·0 multiplied by 0·535 (12·3) is the percentage of carbon which the albuminate of pease contains; and 62·65 multiplied by 0·444 (27·81) is the carbon of the carbonaceous element.

245. **Potassium** and **sodium** enter into the formation of almost every part and are both essential to healthy life. They are not interchangeable in function, notwithstanding the resemblance between their chemical properties, potassium being the tissue alkali, while sodium is chiefly confined to the inter-cellular fluids. They are present in combination with chlorine and phosphoric acid. They are supplied by animal and vegetable food and by most drinking-waters. Sodium chloride is almost universally eaten in addition to foods proper. The quantity of sodium necessary to health is considerably larger than that of potassium. The needful amount of the former may be estimated as 110, of the latter as 50 grains.

246. **Calcium** is no less important than the alkaline metals. It not only enters largely into the constitution of the bones and is, therefore, necessary for their growth and repair, but it is also essential to cell-growth in every tissue. It is for the most part in combination with phosphoric acid. About three grains in twenty-four hours are required. Present in every soil, it is supplied to animals by vegetables, and water is rarely free from it. **Magnesium** also is necessary to bone-structure, but in less amount than calcium. The needful amount may be stated as two grains. **Iron** is essential to the red blood-corpuscles. It is present in almost every tissue and found in almost every food.

247. **Chlorine**, supplied by chlorides, as sodium chloride, and present in most other foods, is readily disengaged within the system to form hydrochloric acid, which is specially active in the digestion of albuminates. The average quantity required is 110 grains. **Phosphorus**, chiefly as phosphoric acid, but also in some other condition in the albuminous tissues, is of great importance. It enters largely into the composition of bone and nervous substance and the acid combines readily with the alkalies and alkaline earths. It is supplied from the albuminates and in combination is found in almost every food. The quantity necessary to be supplied in twenty-four hours may be approximately stated as 25 (14 to 35) grains. **Sulphur**, as such, constitutes nearly ·2 per cent. of albumen. Sulphuric acid also is present in the system in small amount, about 20 grains being required daily. Albuminates and certain vegetables, as cabbage and onions, supply sulphur and drinking-water is rarely free from sulphates.

248. It is necessary to be on our guard against taking too chemical a view of food, especially while our knowledge of vital chemistry is so defective as at present. It is not enough to supply to the digestive system the required elementary bodies in proper quantities and proportions. They must be combined together in certain definite ways, into certain fundamental dietetic principles, in order to constitute food. Before, however, entering upon a consideration of these combinations and of the classification of alimentary substances, the quantity of food in general demands attention.

249. The **quantity** of nutriment necessary to healthy life varies with *sex*, *age*, *climate*, *individual peculiarities*, *nature of the food* and degree of *exertion*. Women on the whole require less food than men, but the difference depends rather on the last mentioned cause than on sex.

250. As to **age**, an infant requires three times as much carbonaceous, and six times as much nitrogenous, food, in proportion to its weight, as an adult. About its tenth year a child needs half as much nutriment as a grown person; in the fourteenth year fully as much.

251. Cold **climates** and cold seasons demand more food than hot, chiefly on account of the greater expenditure for the maintenance of animal heat. More exertion, also, will probably be made. Indian dietaries should be arranged with regard to this principle, and persons coming to India from Europe should neither expect nor gratify, nor seek to obtain by stimulation, a European appetite for food.

252. **Individuals** vary in size, in power and rapidity of digestion, in activity of circulation, in muscular and mental movement even in a state of rest; and these and similar variations affect the quantity of food required for efficient nutrition. Habit also has much influence. Many adults have acquired, by being over-fed in childhood or by self-indulgence afterwards, a craving for food in excess of their real wants. The total, therefore, ranges between rather wide limits and cannot be stated with near approach to accuracy. The quantity for male European adults is said to be from 34 to 46 ounces of what is commonly called "solid" food and 50 to 80 ounces of water. The distinction between solid food and anhydrous or water-free food must be remembered, and the fact that a large proportion of the

water which the system requires is taken with the so-called solid food. If a food is difficult of digestion more of it will be required, because some will pass off by the bowels without contributing to the support of the body. So also food which properly prepared is readily digestible may be wasted by being insufficiently cooked.

253. Lastly, the quantity of food necessary in any particular case fluctuates according to the degree of exertion. In the dietetic management of large classes, as of soldiers or prisoners, it must never be forgotten that increased work demands increase of food; without which the work can either not be performed at all or only at the expense of diminished strength and impaired health. The rations of soldiers on march or in a campaign and of prisoners compelled to undergo severe labor should exceed those suited to ordinary circumstances. An average adult at average work requires from one-twenty-sixth to one-twentieth of his own weight of *food, including drink*, in 24 hours. The necessary quantity of anhydrous food is stated at a hundred and fifth of the weight of the body, about 0·15 oz. for each pound. In absolute numbers an average adult nearly at rest requires, in 24 hours, 18·5 oz. of anhydrous food; undergoing moderate exertion, 23 oz.; with great exertion, 26 to 30 oz.; and under circumstances of unusually great effort even 40 oz. may be required. The water of the food needs also to be increased as exertion becomes greater, but not in the same proportion as the solid or the anhydrous food. The amount of fluid varies between very wide limits, according to temperature, individual habits &c. As a rough approximation to accuracy it may be stated that the liquid bears to the solid part of the food a ratio varying between two to one and equality; that the ratio of water to anhydrous food is as four or five to one; that about 0·5 oz. of water (as drink and in solid food) is required for each pound of the body's weight under average circumstances; and that the absolute quantity of water required by the system ranges from 80 up to 120 ounces according to the degree of exertion. It may be added that the quantity of drink or liquid food ordinarily required in 24 hours is taken to range from 60 to 80 ounces. Finally, it is to be borne in mind that when dietaries are being constructed for large bodies of men error by excess of food rather than by deficiency is to be preferred.

254. Food, generally, may be **deficient** in quantity. Lassitude, incapacity for work, increased liability to disease and a high rate of mortality will be the direct results; while indirectly mischief may be caused by the eating of substances unfit for food in order to satisfy chronic hunger. The direct effects were abundantly illustrated in some of our jails before the revision of the dietaries; though want of variety of food and unscientific choice of alimentary substances, no doubt, contributed to produce the high rates of sickness and mortality. Sepoys quartered in expensive stations, or involved in debt through frequent moves, or permitted to encumber themselves with collateral families, or on foreign service separated from their own families and anxious to save as much as possible for their benefit, not unfrequently exhibit military inefficiency due to inadequate nutrition.

255. The distinction between acute and **chronic starvation** is a most important one for the hygienist and the statesman. In the former there has not been time for the occurrence of those degenerative changes in the digestive apparatus and in the tissues generally which, in the latter, render recovery of health and strength, by means of improved nutrition, improbable or hopeless. The symptoms therefore of chronic starvation demand careful study.* They may be briefly summarized as:—*anæmia*, first shown by pallor of the mucous membranes: *wasting*, exhibited first in the disappearance of the subcutaneous, and subsequently of the deeper, fatty tissue; especially in the gluteal,† pubic, inguinal, and mammary regions: *lethargy*, and *indifference* to life and everything else, probably a result of wasting of nervous tissues: a form of *land-scurvy* due to defective quality of the food, chiefly to the absence from the dietary of fruit and vegetables, shown by discoloration and thickening of the gums (especially of the upper jaw) and leading to a low form of diarrhœa or dysentery, or to general anasarca; a peculiar condition of the epidermis,

* The best and, so far as I am aware, the only complete description of the effects of famine on the human subject is that published by Surgeon-Major Cornish, Sanitary Commissioner for Madras, as an Appendix to his Report for 1877.

† "An unequivocal and almost universal sign of chronic starvation," says Mr. Cornish, "*was flattening of the nates.*"

so characteristic as to deserve the title of *famine skin;* the surface, especially on the neck, chest, trunk, and between the shoulders, being harsh, dry and scaly with degenerated epithelium: and a lightening of the color of the *hair* due to atrophy of the pigment cells, often accompanied by excessive growth. In addition to these results of deficient nutrition, the reproductive system is deeply affected, so that conception is rare and the fœtus imperfectly nourished.

256. The ill-effects of food in **excess** of the wants of the system are less commonly observed and less formidable than the results of deficiency. Most healthy persons in circumstances above the poorest take more food than they require and, in the vast majority of cases, with impunity; though it is at least possible that the digestive machinery would last longer and the average duration of life be increased if sufficient food only were eaten and drunk. Occasionally, however, persons with ill-regulated appetites, or after long deprivation of food, devour more than the system can dispose of in the ordinary way. The excess behaves as animal or vegetable matter exposed to heat and moisture, outside the body, would behave. It putrefies, generating carbonic acid and sulphuretted hydrogen, which cause the inconvenience and sometimes the severe pain of flatulence, as occurs when cattle are allowed access to unlimited quantities of green food. Other products of putrefaction irritate the intestinal tract, setting up diarrhœa, which is not always sufficient to remove the peccant matter. Again, putrid fluids may be absorbed and entering the blood produce effects of a more serious character than those mentioned above. Lastly, the excess of food may enter the system by active digestion and assimilation in the ordinary way, with results varying according to the dietetic principle which was in excess, and to be considered hereafter.

257. There may be also what may be called **relative excess**; where the absolute quantity of food is not too great, but its distribution through the day is faulty. On the one hand, meals may be too few. It is true that in this matter the utmost variety of practice exists in different races, different sections of the same race and different individuals. In this country, for instance, some natives eat once only in the day, most twice, many thrice; and all

these various customs seem equally compatible with health. Habit induces the digestive system to submit to practices which hygiene disapproves. On the other hand, meals may be too frequent, or eating may be so nearly continual that meal-times become merely nominal and the digestive apparatus gets no rest except at night. This state of things is not uncommon in the treatment of European children in India, who are often encouraged to eat at all hours under the erroneous impression that they do not take sufficient nutriment at the regular hours for meals. Digestion is thus deranged, dyspepsia and consequent malnutrition engendered; and in some cases a permanent habit of over-indulgence in food created.

258. So far as it is possible to lay down general rules for **meals**, it may be said that four or five hours should not be exceeded as an interval between two meals in the hours of daylight and work, and that three meals in the day are sufficient for adults. In the case of children food should be supplied at intervals of not less than three or more than four hours. When the meals are breakfast, an early dinner and tea or supper, (or correspond to these), the total daily food should be distributed amongst them by allotting three parts to the first, four to the second, and two to the third. When dinner is eaten late, four-ninths of the daily supply may be taken then and half that quantity at an afternoon meal.

259. It has been already said that it is by no means sufficient for the maintenance of life and health that certain quantities of the elementary constituents of the body should be supplied. Other conditions also must be fulfilled. First of these it is found to be necessary that the elements should be grouped into certain definite compounds; and, accordingly, foods proper contain one or more of such groups, or fundamental **alimentary principles**, on the amount and proportions of which the sufficiency of a dietary to health depends. They are *albuminates*, *fats*, *carbo-hydrates*, *salts* and *water*.

260. The ALBUMINATES are a group of substances including albumen and other bodies closely resembling it or identical with it in chemical composition, as fibrin, casein,

hæmatoglobulin &c., in the animal,* and legumin, gluten &c., in the vegetable kingdoms. Containing nitrogen, as well as the other three organic elements, they are sometimes called *nitrogenous* or *azotized* principles; and from the fact that their primary function is the formation and repair of muscular and some other tissues, the term *plastic* is not unfrequently applied to them. Their composition includes, besides the organic elements, small quantities of sulphur and phosphorus. Their presence in food is indispensable.

261. The albuminates are **necessary** for the maintenance and repair of the nitrogenous tissues of the body, without which the development of energy is impossible, and in proportion to the activity and vigor of which, force, potential or actual, is generated. The oxidation of their nitrogen and carbon contributes to animal heat and other force, and they are capable of conversion into fat; but the value of nitrogenous principles in the food rests mainly upon the indispensability of the nitrogenous tissues to the sufficient absorption of oxygen by the lungs and its utilization within the system. The chief duty of animal life is the development of force by the oxidation of the carbon and hydrogen contained in the blood, and to this process the presence and action of the nitrogenous tissues appear to be essential. The latter are capable of directly supplying the materials for muscular power and other forms of force in cases where non-nitrogenous food is deficient in amount; but it is in this contingency only that the decay or oxidation of muscular tissue is necessary to the development of energy. Thus, increased muscular effort does not, under ordinary circumstances, lead to increased excretion of nitrogen, as it would if force were due to waste of nitrogenous tissues; but when food consists largely of albuminates, as when health is maintained upon an exclusively *flesh* diet, the excretion of nitrogen by the kidneys and bowels is greatly augmented without increased exertion.

262. The **quantity** of albuminate necessary to health varies, of course, with the degree of exertion undergone.

* Gelatin, chondrin and some other animal albuminates are inferior in nutritive power to albumen &c.

Two ounces of *anhydrous* albuminate are required in 24 hours for the internal inevitable work of the body, and this amount is the minimum consistent with life. A state of rest requires 2·5 oz.; easy work, 4·2 to 4·6, (3·5 being considered the minimum allowance for a working man); hard work will demand 5·5 oz.; and *very* hard work, as that of a soldier marching or in the field, 6·5 to 7 oz. These quantities are based upon observations made upon average Europeans and European labor. They will probably be found too high for Natives of India.

263. When the supply of albuminous food falls **below** the minimum, the functions of circulation, respiration, digestion &c., cease to be efficiently performed. An ounce or an ounce and a half only, for instance, of anhydrous albuminate given daily will be followed by great debility of the muscular system and a generally adynamic condition, with increased liability to specific diseases, especially malarial, and to pneumonia. The effects of a dietary from which albuminates are altogether excluded, but which is normal in other respects, supervene in a few days. Muscular strength suffers first, mental power not until subsequently; fever and dyspepsia follow; an anæmic condition is developed. The excretion of urea, and in a less degree of uric acid, is diminished. The weight of the body may be maintained for seven or eight days provided abundance of starchy food be supplied. Death by starvation would be the ultimate result of such an experiment. Adults are very rarely in danger of receiving an insufficient supply of albuminous food, except perhaps prisoners who have no power of selection; but infants are in too many cases fed almost entirely on arrow-root, sago and other starches, containing scarcely any nitrogenous aliment.

264. The effects of **excess** of albuminates depend on the digestive powers and the habits of the individual. Most men eat more albuminous food than is necessary for the wants of the system, without ill effect, a considerable proportion of the excess probably passing away undigested with the fæces. Those who live almost wholly or altogether upon flesh, obtaining from it carbon in sufficient quantity for nutrition, necessarily take excess of nitrogenous matter, and with impunity so long as very active exercise

(increasing absorption of oxygen and rapidity of circulation) is taken. The prize-fighter in training, mentioned before, disposed of 9·8 oz. of albuminous food, *besides* an ample allowance of fat and starch, without apparent injury. Such impunity, however, does not always follow. A plethoric condition, with congestion and consequent enlargement of the liver, is apt to follow the continued absorption of albuminates in excess, unless the amount of exercise is also increased so as to promote absorption of oxygen. Excess of force, evinced by irritability of temper and even savageness of disposition, has been assigned to this cause. Without active exercise oxidation is imperfectly performed, excrementary substances are retained in the system, or being incompletely elaborated (falling short of urea, corbonic acid and other complete excretions), irritate the excreting organs. Hence probably, in some cases, gouty affections. Great excess of albuminates, without other food, was found in Hammond's experiments, to produce in five days, fever, diarrhœa and, if long continued, albuminuria.

265. The **nitrogenous foods** which chiefly supply albuminates are :—*milk*, *cheese*, the *muscular tissues* of animals, *eggs*, the seeds of *cereals*, and of *leguminosæ.* In all of these, as will appear hereafter, other alimentary principles, besides the albuminates, are present. None of them (except milk, and that only during infancy) is fit to constitute an exclusive diet.

266. The FATS and the carbo-hydrates, composed almost wholly of carbon, oxygen and hydrogen, are sometimes classed together as *carbonaceous* foods. Containing no nitrogen they are also called *non-nitrogenous ;* and, on the theory that their oxidation in respiration is the source of animal heat, *respiratory*. Their oxidation is the principal source of energy as exhibited in muscular action. Although, however, the two groups are closely connected in function and may, under certain circumstances, replace each other in food, we are justified, in the present state of our knowledge, in maintaining the distinction between them ; and in stating that, to the human subject at least, fat, as such, is an essential element of nutrition. It is now acknowledged that albuminates are converted

into fat in the system;* but, on the one hand, all known freely chosen dietaries contain fat; and, on the other, a diet consisting of albuminates, starch and salts, without fat, is found to be incompatible with human health.

267. The **functions** of fat are manifold. It is necessary for the repair of tissues, as the muscular and the nervous; and from this point of view it is a plastic food. It is a digestive agent of great power; albuminous substances yielding more rapidly to the action of the stomach when fat is present. Its oxidation is one of the chief sources of animal heat and other forms of force, and we have seen that in this particular it is nearly two and a half times as powerful, weight for weight, as starch. It aids in all the nutritive processes, and in the removal of effete tissues; while it protects albuminous tissues from disintegration.

268. The **quantity** of fat required for efficient nutrition varies with the degree of exertion undergone; and increased effort demands increased supply of this aliment as well as of albuminate. The amount necessary for the internal work of the body, in the case of an average adult, may be stated as 0·5 oz. In a state of rest one ounce will be required; under ordinary circumstances of labor 2·5 to 3 oz. should be allowed; and, when the work is very laborious, 3·5 to 4·5 oz.

269. When fat in **excess** of the wants of the body is taken, up to certain limits, varying with the individual and the kind of fat, it is absorbed; beyond them it passes off by the bowels. Animal fats are more readily absorbed than vegetable. Thus in one set of experiments from 1 to 1·5 oz. of animal fat was found to be absorbed (in addition to that contained in the ordinary diet) in 24 hours, while of vegetable oils not more than 0·7 oz. was so disposed of. That portion which is absorbed may be stored up in the body, leading to obesity and fatty degenerations; or yield-

* Voit and Pettenkofer maintain that fat is altogether formed from albuminoid and other nitrogenized foods; and that there is no direct relation between the carbo-hydrates ingested and the fat formed within the system. The carbo-hydrates protect fat already formed from decomposition: and each quantity of albuminous food requires the presence of a corresponding quantity of carbo-hydrate in order to the complete deposition of the amount of fat due to the former. 100 parts of water-free albumen yield 51·4 parts of fat.

ing fatty acids by decomposition it may produce excessive acidity in the system. The metamorphosis of nitrogenous tissues is delayed by fat and in this way also excess may be mischievous.

270. The specific effects of **deficiency** of fat in food are not well known; but it is established that depravation of health, in the human subject at least, follows their exclusion, even though carbonaceous food of the other group be abundantly supplied. Herbivorous animals are able to convert sugars and starches into fats and thereby to dispense, to a great extent, with a direct supply of this alimentary principle; and in man also the same process is to a certain degree carried on, but not sufficiently to compensate the absence of fats themselves. Hunters living exclusively, and amply supporting health and strength, on the flesh of animals are only apparently exceptional; all meat, even that of wild animals, including a considerable proportion of fat. The benefit which so often follows the use of cream, suet and cod-liver oil as therapeutic nutrients, in cases where the diet includes the other principles in sufficient quantity, confirms the opinion that fat, as such, is an indispensable element of human food.

271. The animal fats **supply** most of this class of nutriment, the chief sources being *butter* or *ghee*, *suet* and *lard*. *Gingelly*, *cocoanut* and other vegetable oils are also used in the preparation of food. Many aliments primarily belonging to another class include considerable proportions of fat in their composition—meat, for instance, fish, eggs, maize &c. &c.

272. THE CARBO-HYDRATES are so called because they are composed of carbon, with hydrogen and oxygen in the same proportion as that in which they constitute *water*, *i.e.*, in the ratio of two atoms to one. They are divided into three groups;—the *amyloses*,* including starch, dextrin and cellulose; the *sucroses*,† which include ordinary sugar derived from sugar-cane, beet &c., and lactose or sugar of milk; and the *glucoses*‡ or grape-sugars. This class of food is not indispensable to life or health, and it is certain that both may be maintained on a diet from which carbohydrates are excluded. Though not, therefore, necessary,

* $C_6H_{10}O_5$. † $C_{12}H_{22}O_{11}$. ‡ $C_6H_{12}O_6$.

they nevertheless enter into the dietaries of every people and of every individual so circumstanced as to have a choice of food. Of the three sub-divisions the starches are by far the most important, the sucroses coming next. All three, being digested, are taken to be equal in nutritive value; but they differ much in digestibility. One amylose, for instance— cellulose— scarcely yields at all to human digestive organs. The sugars are much more readily absorbed than starch.

273. The carbo-hydrates are not plastic; at least they do not aid in the maintenance of the solid tissues, though the fluids of the body are nourished by them. In other respects their **functions** are the same as those of the fats. By oxidation of their carbon they yield force and heat, but containing in their own constitution the means of oxidizing their hydrogen, without the aid of respiration, they are (as we have seen) much inferior in that respect to fat. Supplied in abundance they save both the nitrogenous and the fatty tissues from destructive metamorphosis, being more readily oxidized than either. As has been seen, their conversion into fat in the human system is strongly doubted: although in herbivorous animals this metamorphosis unquestionably occurs. When the supply of carbohydrates is insufficient for the respiratory and other wants of the system a demand for the deficiency will be made upon the already-formed fat. In this way the increase of total weight apparently due to use of this class of food may be explained.* In this respect sugar is superior to starch. It is possible that starchy foods favor digestion by their superior bulk, the digestive organs requiring a certain degree of volume for effective action, and perhaps also such retardation as the less nutritive ingredients of food produce. Lastly, from the carbo-hydrates are derived lactic and other acids to which the acidity of some of the fluids is due and which in other ways appear to play an important part in nutrition.

274. Amylaceous and saccharine food not being indispensable the **quantity** consistent with health varies widely. We may take 12 oz. of anhydrous carbo-hydrates as the amount desirable in 24 hours in a state of absolute rest,

---

* Mr. Banting found that 5 oz. of sugar taken daily with his food for 7 days added one pound to his weight.

14 oz. in ordinary labor, and 16 to 18 when the work is very hard.

275. When **excess** of starchy food is taken, much passes away undigested by the bowels, the proportion varying with the digestibility of the particular article, its mode of preparation and the digestive power of the individual. Habit also has great influence, the organs undergoing modification both in the individual and in the race, which bring them into conformity with the customary food. A person accustomed to a mixed diet, if compelled to live almost exclusively on rice or on potatoes, would pass off by the bowels a much larger proportion of starch at the beginning of his new dietary than after it had become established. When too much starch (or sugar) is digested and absorbed, it, like fat, delays the metamorphosis of the nitrogenous tissues and is itself converted into fat; thus producing obesity and sometimes fatty degeneration of the heart and other structures. Imperfect digestion of excess of carbohydrates generates acidity and flatulence of the intestinal tract. Saccharine urine is occasionally a result of excessive ingestion of starchy food and diabetes mellitus is a frequent disease among brahmans and others living mainly on carbohydrates.

276. Partial or total **deprivation** of carbo-hydrates can be borne by man, provided fat in corresponding excess be supplied. Health is incompatible with the exclusion of both groups of carbonaceous aliments. Enough of albumen might be digested to give the requisite amount of carbon, but nitrogen would then be greatly in excess of the powers of the system to assimilate it, unless much exertion were undergone and then carbon would be again deficient.

277. The substances which **supply** starch almost exclusively are *arrowroot*, *sago*, *tapioca*, the so-called *corn-flour* and other similar articles. The *potato* and the seeds of the *cereals* also contain a very large proportion of amylaceous matter. *Sugar* and *molasses* or *treacle* are obtained principally from the juice of the sugarcane, but *jaggery* is also supplied in large quantities, in this country, by the sap of the cocoanut tree and of other palms. The sugar of *milk* belongs like these to the sucrose group. The glucoses are found in *fruits* and *honey*, and grape-sugar is sometimes

manufactured, both in the crystallized and uncrystallizable forms, on a large scale, by the action of dilute acid upon starch. This artificial glucose, however, though equally valuable with sucrose as a food, is inferior in sweetening power (owing to its lower degree of solubility in water), and is not likely to be knowingly employed except as an adulterant of cane-sugar.

278. Before passing on to inorganic food it will be well to inquire into the relative values of the three foregoing alimentary groups with reference to the production of force. At present it is believed that animal heat is chiefly, if not altogether, due to the conversion of potential energy into muscular force; and that the non-nitrogenous parts of the food are mainly the materials, by the oxidation of whose carbon and hydrogen, in the processes of respiration and circulation, potential energy is developed, the normal condition and adequate repair of the nitrogenous tissues being necessary conditions of its development. We know that the muscular powers of the body can be maintained for a time and a considerable amount of labor performed while non-nitrogenous food only is ingested; the motor force being supplied by the latter until the albuminous tissues by whose action it is maintained fall gradually into disrepair and impotency through deficiency of nutrition. We know also that, assuming (as we are justified in doing) that the thermotic power of foods, *i.e.*, their capacity of producing heat by the oxidation of their elements, is a measure of their mechanical or mortor power, independently of their including nitrogen or not, the oxidation of muscular tissue is quite insufficient to account for the work which the muscle performs; it follows that the greater part of the force, potential or actual, developed in the body, is due to the non-nitrogenous constituents of the food and to the oxidation of their carbon and hydrogen; the carbon and hydrogen of the nitrogenous tissues also contributing an appreciable but inferior share. The chief functions of the albuminates is to repair those tissues without which the development of energy by the carbonaceous foods is impossible. The direct production of force by them is secondary and comparatively unimportant. On the other hand, the chief duty of the carbonaceous food is the production of force, either in the form of muscular power or of animal heat or in other modes. Further, albuminates are inferior as generators of energy not only because their thermotic power, supposing them to be completely oxidized, is less, but also because they are not fully oxidized in the system, while the carbon and hydrogen of carbonaceous foods are, when absorbed, wholly converted into carbonic acid and water. Urea is an incompletely oxidized product of nitrogenous food.

279. Force is *measured* either in *kilogrammeters* or in *foot-tons*, which are the French and English force-units, respectively. The former expresses the force necessary to raise a kilogram, against the force of gravity only, one meter: the latter, a ton one foot. In the following Table (as throughout this chapter) the English notation is employed; the numbers being convertible into the corresponding figures in metric notation, *i.e.*, kilogrammeters from a gram, by dividing each by

0·09157.* One ounce of any of the substances given below, (in the natural, not the anhydrous, condition), if taken as food and fully oxidized in the system, theoretically generates an amount of energy capable of raising to a height of one foot the number of tons which the figure opposite to it expresses.

Foods.	Foot-tons.	Foods.	Foot-tons.
Ale (Bass' bottled) ..	30	Flour	148
Arrowroot	151	Ham (lean, boiled) ..	65
Bacon (dried)	291	Milk	24
Beef (salt)	52	Milk (skimmed) ..	20
Beef (lean)	55	Oatmeal	152
Bread (crumb) ..	83	Pea-meal	146
Do. (crust)	160	Pemmican	275
Butter	281	Pork (fat)	201
Cabbage	16	Do. (salt)	69
Carrots	20	Porter (Guinness') ..	41
Cheese (Cheshire) ..	168	Potatoes	38
Cream	96	Poultry	51
Egg (white)	22	Rice (ground) ..	145
Do. (yolk)	127	Sugar (lump)	129
Fish (white)	43	Veal (lean)	45

280. As we are to **guard against** taking too chemical a view of food, so also we should accept with caution calculations of the amount of energy which different foods are capable of generating. It is to be remembered that such estimates assume that the whole of the food is oxidized, and that this implies that it is of such a nature and so prepared that the system can assimilate it completely. Again, an aliment may be in fact far inferior as a nutrient and generator of force to what potentially and theoretically might be expected: as is the case with gelatine, which is superior to boiled ham (for instance) in the number of heat-units which it generates when burnt in oxygen, whereas it is well known to be far inferior in nutrient power. There may also be differences in the *kind* of potential energy evolved from different foods yielding theoretically equal amounts. Thus it is maintained by some, and with great plausibility, that fully fed carnivora are capable of more powerful effort in a shorter time than herbivorous animals, while these are more enduring of sustained exertion, and that meat-eating and vegetable-eating races exhibit the same distinction. It is certain that the digestive process and perhaps consequently the evolution of potential energy are slower in the herbivora and that this difference may account for the other if proved to exist.

* The numbers in the Table have been calculated by Professor Parkes from grams and kilogrammeters by multiplying first by 28·35 (the numbers of grams in an ounce) and then by 0·003229: or, in one operation, by 0·091 (the ratio of kilogrammeters to foot-tons).

281. The SALTS constitute the fourth group of alimentary principles and their presence is equally indispensable with that of the first or second class. They are essential to the growth and maintenance of the tissues and fluids of the body, and the special functions of the bases have been given, so far as they are known, in the beginning of the Chapter. One most important section of the salts is formed by the combination of lactic and certain vegetable acids with the alkalies and appears to render some of the fluids alkaline and to be convertible into carbonates in the system. Such are lactates, tartrates, citrates, malates and acetates of potassium or sodium, preferably of the former. The carbonates cannot be substituted for these salts.

282. The necessary **quantity** of this kind of food may be stated as 0·5 oz. in a state of absolute rest; 1 oz. in moderately laborious work; and 1·2 to 1·5 when the labor is very severe. As these substances, with one exception, are not isolated articles of food but are contained in others, they are not likely to be taken in **excess. Deficiency** of salts exercises a very unfavorable influence upon health, impairing the efficiency of the tissue to which their presence in sufficient amount is necessary and leading (especially when the vegetable acids are withheld) to that form of malnutrition which is called scorbutus. The exception above referred to is the sodium chloride or common salt. An insufficient supply of this article of food undoubtedly favors the propagation of intestinal worms; and, unless chlorine is otherwise supplied, the formation of hydrochloric acid for the digestive process will be impossible. The amount of salt which is required in 24 hours varies with the nature of the other articles of the dietary. Thus, 100 grains are, perhaps, sufficient in jails where the staple food is wheaten flour, while at least twice this quantity will be required with a rice diet. It is scarcely possible to lay down a general rule on the point* except this, that excess can do no harm,† while deficiency must be injurious, and

* In the French Army the allowance of salt is 0·5 oz.; in the Navy, 0·77. In the Prussian Army 0·87; in the Russian, 1·59; in the English about 0·25. Numerous experiments made in England and France have shown the amount of salt daily excreted under ordinary circumstances to range from 0·4 to 0·6 oz.

† More than an ounce may be taken in 24 hours without the appearance of any in the fæces.

that it is a mistake to economize by reducing the ration of so cheap and necessary an article of food as salt, at the risk of impairing health.

283. The salts of the food, then, are supplied by *sodium chloride* taken separately and by the saline constituents of the other articles of diet, including water. *Vegetables* and *fruit* supply the antiscorbutic salts and acids, and *citric acid* is substituted when these are not procurable. The following Table shows the amount of salts derivable from one pound of some ordinary articles of food. The specific salts present in each of these and other articles of food will be given, so far as may appear necessary, when each comes to be separately considered.

284.

	oz.		oz.
Bacon, dry	0·46	Malt-liquor	0·03
Do. green	0·34	*Meat, cooked	0·47
Barley-meal	0·32	*Do. uncooked (one-fifth deducted for bone) ...	0·26
Beef, fat	0·70	*Do. of fattened cattle (do.)	0·59
Do. lean	0·82	Milk, new	0·13
Do. salt, uncooked ...	3·37	Do. skimmed	0·13
Biscuit	0·27	Mutton, fat	0·56
Bread, average	0·21	Do. lean	0·77
Butter and fats ...	0·32	Oatmeal	0·48
Butter-milk	0·13	Parsnips	0·16
Cabbage	0·11	Pease, dry	0·40
Carrots	0·16	Pork, fat	0·37
Cheese, Cheddar ...	0·72	Potatoes	0·16
Do. skim-milk ...	0·78	Poultry	0·19
Cream	0·29	Rice	0·08
Egg, entire	0·24	Salmon	0·22
Do. white	0·26	Tripe	0·38
Do. yolk	0·21	Turnips	0·10
Flour, wheaten ...	0·27	Veal	0·75
Liver, bullock's ...	0·48		
Maize-meal	0·27		

285. A sufficient supply of WATER is even more necessary to life than food of any other class, and death by starvation takes place much more rapidly when water also is excluded than when the other aliments only are withheld. All the tissues require water for their composition;

* From Professor Parkes

their vital processes are impossible without it; and the aqueous exhalations and excretions from the lungs and kidneys have to be replaced. The **quantity** of water which the system demands varies with the amount of work, the external temperature and, to a greater degree than even the other elements of the diet, on individual peculiarities and habits. The necessary amount may be stated to be, on the average, half an ounce for each pound of the body's weight; or 70 to 90 ounces for an adult man. If more is taken than is actually required, the excess, in a state of health, rapidly passes off by the kidneys and the skin. Deficiency leads to remarkable failure of the physical and mental powers. When great exertion, therefore, has to be undergone an ample supply of water should be provided.

286. A considerable proportion of the necessary amount of water is **supplied** in the so-called "solid" food, especially by the vegetable part of it, leaving a variable quantity to be taken as actual drink, a quantity which ranges from 50 to 100 ounces. It is indifferent in which of these two ways the supply is maintained, provided only it be sufficient; and it is therefore needless to give details of the proportion of water included in various articles of food. The imperious demands of thirst will ensure that deficiency of water in the solid food will be compensated by liquids. The aqueous constituent of solid food is consequently unimportant, except in so far as it diminishes the nutrient value of the aliment in other respects in which it is not so easy to apply a remedy.

287. Water itself or other **drinks** consisting of course principally of water, but containing other substances which communicate flavour or other qualities to it, are always necessary in addition to the water of the solid food. Some of the latter (as *milk*, *butter-milk &c.*,) are nutritive in addition to their water-supplying quality; others (as *wines*, *spirits*, and *malt-liquors*) are nutritive and stimulant; others (as the alkaloidal beverages, *tea*, *coffee*, and *cocoa*) exert sedative or other influences on the nervous system. In one or more of these forms rather than as mere water the majority of civilized mankind imbibes the water necessary for life and health.

288. We have seen that one of the alimentary groups (the carbo-hydrates) is not indispensable and that therefore

it might be replaced in a dietary by another principle (fat); also, that when effort is increased food must be increased, some kinds of food (albuminates and fat) in greater degree than others. The **proportion**, then, which the several dietetic principles should bear to each other does not admit of being stated with any great accuracy. As a rough approximation the following numbers may be taken as a convenient representation of the relation in quantity of the four solid groups of food in a wholesome dietary—albuminates 9, fat 5, carbo-hydrates 28, salts 2.

289. **Other conditions** besides those which have been considered are necessary to efficient alimentation. In the first place, the food must be of such a nature and so prepared that a sufficient quantity shall be *eaten* and, being eaten, shall be *digested*. There is seldom any difficulty in securing the first point in the case which is most frequently presented, that of free healthy men compelled by their circumstances to undergo daily physical labor. In other cases, however, as with the sick, the idle or the overworked, appetite for food may be deficient and may require stimulation. Variety, either in the food or in the mode of its preparation, is one ready means of increasing desire for it; and this is especially expedient in jails, where monotony is an essential of discipline, where mental depression, to some extent, is almost universal, and where the inmates are absolutely restricted to their dietary and debarred from even trifling variations within the reach of the poorest free laborers. The use of condiments is another means of maintaining appetite for food at a healthy level, by imparting agreeable and stimulating flavors to insipid substances. It is scarcely credible, for instance, that hunger (falling short of starvation) would be sufficient inducement to rice-eaters to consume enough of so tasteless a food for their wants, were it not for the various condiments which are invariably eaten with it. It should be remembered that while variety and condiments are thus useful in stimulating an insufficient appetite they are capable of great abuse by being employed to excite appetites which needed no stimulation and thus to favor the ingestion of food in excess of the wants of the body.

290. **Digestibility** depends upon the nature of the food, and the manner in which it is prepared for use. Chemical identity or resemblance affords no certain indication of

equality in capacity for digestion. Thus cellulose is isomeric or polymeric with starch, but the former resists human digestive organs completely, while the latter is readily assimilated. So also vegetable albumen is less digestible than muscular tissue. Food must be selected, therefore, with reference to the digestive powers of the class or of the person, and these are largely influenced by habit, hereditary or individual. A rice-eating people, for instance, will be unable to maintain health on a diet of the less easily digested dry-grains, until time and habit have modified its digestive system; and men accustomed to derive their nitrogenous nutriment from flesh would fail to extract it from an equivalent quantity of pease or of cheese. Besides such wide differences as these and independently of individual peculiarities, articles of food vary considerably in the time required for digestion, and, therefore, in their suitability to different meals or to different states of health, the sick especially requiring attention to this point on account of the weakness of their assimilative powers; and tables have been constructed to show relative facility of assimilation of the ordinary articles of food. A few of these are given here in the order of their digestibility in the following Tables :—

291. **Animal Foods.**

Articles of Diet.	How cooked.	Time of chymification.	
		Hours.	Minutes.
Pig's feet, soused	Boiled ..	1	0
Tripe, soused	....	1	0
Eggs, whipped	Raw ..	1	30
Salmon-trout	Boiled ..	1	30
Venison-steak	Broiled ..	1	30
Brains	Boiled ..	1	45
Ox-liver	Broiled ..	2	0
Cod-fish, cured	Boiled ..	2	0
Eggs	Roasted ..	2	15
Turkey	Boiled ..	2	25
Gelatine	Do. ..	2	30
Goose	Roasted ..	2	30
Pig, sucking	Do. ..	2	30
Lamb	Broiled ..	2	30
Chicken	Fricasseed ..	2	45
Beef	Boiled ..	2	45

Articles of Diet.	How cooked.	Time of chymification.	
		Hours.	Minutes.
Beef	Roasted ..	3	0
Mutton	Boiled ..	3	0
Do.	Roasted ..	3	15
Oysters	Stewed ..	3	30
Cheese	Raw ..	3	30
Eggs	Half-boiled ..	3	30
Do.	Fried ..	3	30
Beef	Do. ..	4	0
Fowls	Boiled ..	4	0
Do.	Roasted ..	4	0
Ducks	Do. ..	4	0
Cartilage	Boiled ..	4	15
Pork	Roasted ..	4	15
Tendon	Boiled ..	5	30

292. **Vegetable Foods.**

Articles of Diet.	Time of chymification.	
	Hours.	Minutes.
Rice	1	0
Apples, sweet	1	30
Sago	1	45
Tapioca	2	0
Barley	2	0
Apples, sour	2	0
Cabbage with vinegar ..	2	0
Beans	2	30
Sponge-cake	2	30
Parsnips	2	30
Potatoes	2	30
Do.	2	33
Apple-dumpling	3	0
Indian-corn cake	3	0
Do. bread	3	15
Carrot	3	15
Wheaten bread	3	30
Potatoes	3	30
Turnips	3	30
Beets	3	45
Cabbage	4	0

293. **Preparation** of food so as to favor digestion includes cooking, intermixture and the use of condiments. *Cooking* consists essentially in the application of heat in such a manner as to looson the texture of the food and thus promote digestibility, at the same time rendering it more agreeable to the taste. Digestion is favored also by the due *intermixture* of the different alimentary principles; the presence of fat, for instance, aiding the organs to assimilate the other classes. Variety both in modes of cooking and in manner of combining foods promotes digestion as well as appetite. *Condiments* increase the secretion of the digestive fluids and consequently the powers of digestion.

294. Finally, all articles of food must be **sound** and **genuine**. They must be free from spontaneous changes of condition, such as fermentation, putrefaction, parasitic growth, disease or those obscure alterations which the tissues and fluids of healthy animals and vegetables in some cases undergo at certain times, and which generate material of a poisonous nature. They should be also unadulterated; an adulteration being any substance, fraudulently added to a food, which diminishes its nutrient power.

295. It may be inferred from the foregoing pages that the following are the chief points to be attended to in the arrangement of **dietaries**:—(1) The wants of the body under various circumstances of age, sex, constitution, state of health, amount of labor, habits and climate; (2) Selection of food of suitable composition, quality, digestibility, nutritive power and agreeability to taste and appetite; (3) Variety and intermixture of foods so that the appetite may be sufficiently stimulated and digestion promoted; (4) The cooking or other preparation of food, with the same objects in view; (5) The most favorable distribution of the meals through the 24 hours.

296. The ordinary articles of human food have now to be considered separately, and we shall begin with those which have been already enumerated (265) as containing albuminates in greater or less proportion. MILK claims the first place, being the food provided by nature for the young mammal, and because its composition suggested the division of the fundamental dietetic principles as given

above. It includes *albumen* and a kindred compound *casein*, as nitrogenous constituents, a fat called *butter*, a carbo-hydrate called *lactose* or milk-sugar, *salts* and *water*. The relative proportions of the principles are such as are best suited to the nutrition of animals for some months after birth, but milk is not fitted to be the sole food of the adult. If it were taken in sufficient quantity to yield the necessary amount of nitrogen, fat and water would be in excess.

297. Although all milks agree in their general composition, there is considerable **variety** of detail depending upon the *species*, *breed*, *age* and *food* of the animal, the time which has elapsed since *parturition*, the *time* at which the milk is drawn and other circumstances: thus, some breeds of cows yield richer milk, that is, milk containing a larger proportion of fat, than others; the milk of some varieties excels in casein and is better adapted for the production of cheese. Animals of moderate age give better milk, containing less water, than the immature or the old. Sweet foods (as carrots) increase the sugar of the milk; luxuriant pasturage adds to the butter, which is deficient in mountain-fed cattle and in all when the weather is dry and herbage scarce and withered. Whatever food fattens the animal diminishes the richness of the milk. Butter is more abundant immediately after parturition, even when colostrum has ceased to be secreted, and diminishes as the next birth approaches. Evening milk is more nutritious than that drawn in the morning, containing about 3 per cent. more solid matter, about 1·25 per cent. more fat and about 0·5 per cent. more cheese. In animals whose mammary glands have become enlarged into reservoirs in which the milk accumulates and remains undrawn for some hours, the fatty portion rises to the upper part of the collection and the milk last extracted is, therefore, richest.

298. So many circumstances are capable of interfering with the relative proportions of the dietetic principles in the milk of the same animal that the following table, giving a comparative view of the milks of **different species**, must be understood to show only approximate or average results*:—

* Payen.

—	Woman.	Goat.	Sheep.	Ass.	Mare.
Water	89·54	85·60	81·00	90·50	89·33
Butter	3·34	4·10	6·50	1·40	0·20
Sugar and soluble salts	3·77	5·80	4·50	6·40	8·75
Casein and insoluble salts	3·35	4·50	8·00	1·70	1·62
Specific Gravity ..	1030 to 1034	1036	1035 to 1041	1023 to 1035	..

299. The most important milk, because the one most generally used for human food, is that of the **cow**. The composition of this, according to Letheby, is;—water 87·3, casein 3·6, sugar 4·7, fat 3·6, salts 0·8: yielding one part of nitrogenous aliment to 2·3 parts carbonaceous; or, as fat is superior to carbo-hydrate one part to 3·8. Wauklyn states the constituents of 100 c.c. of "average country milk" to be, (in grams);—water 90·09, fat 3·16, casein 4·16, sugar 4·76, ash 0·73; total 102·90 grms. In this country the yield of each animal is very small and the average may probably be stated at three pints in 24 hours.* Cows' milk is a wholesome and highly nutritious

* The following are Professor Macnamara's results of analyses of seven samples of milk taken from Bengalee cows. (*Vide Chemical News, May 30th*, 1873, *p.* 274):—

Age of Calf in Months.	Weight of daily milk in lbs.	Total solids per cent.	Casein per cent.	Sugar per cent.	Fat per cent.	Salts per cent.
1	6½	15·12	5·50	3·98	4·98	0·76
2	5	12·82	4·30	4·40	3·60	0·70
2½	5	15·28	5·76	4·10	4·10	0·84
5	4	11·90	4·30	4·37	2·52	0·78
6	10	12·04	4·30	4·10	3·20	0·70
7	5	11·65	5·40	3·86	1·90	0·82
10	4	11·92	4·20	4·37	3·00	0·68
Mean ..	5·64	12·96	4·82	4·17	3·33	0·75

food for adults no less than for children. In some rare cases where it proves indigestible, warming it (to a degree below that which would coagulate the albumen) removes the objection. When circumstances render a supply of human milk unobtainable for an infant, cows' milk is the best substitute, and for the first seven months it should, with certain preparation, be the only food, starch being added in some digestible form after that period. For a year at least milk should be the staple of the infant's food.

300. When cows' milk is substituted for the natural food of an infant, it is desirable to imitate the latter as closely as possible. Accordingly a little sugar is added; and, because both the casein and the butter of cows' milk exceed those of the woman, it is necessary to dilute with from one-third to one-half of water, which should be of such a temperature that the food may be at about 98° F. From two to three pints of this dilution should be given in 24 hours up to the age of seven months. When the weather is hot and dry an infant may suffer from *thirst*, irrespectively of desire for food. In such a case it will be better to give water alone rather than to overload the digestive organs by increasing the supply of diluted milk.

301. As to the **nutritive value** of milk, calculated from its percentage composition as given in (299), one pound contains 252 grains of albuminates, 252 of fat, 329 of sugar and 56 of salts; total anhydrous food 889 grains. Were milk, therefore, the sole food of an adult undergoing moderate labor, 7 lbs. of it would be required to supply nitrogenous aliment in 24 hours, a quantity which contains more than 4 oz. of fat and a large excess of water.

302. When milk is allowed to stand for some hours, it separates into two strata, the upper of which is called **cream**. Under ordinary circumstances, this consists of about one-half of the fat of the milk mixed with milk and a small amount of casein. When heat is applied, nearly the whole of the butter rises to the surface and the separation is more rapid. When this upper layer has been removed, the remainder is called *skimmed* or *skim* milk. The thickness of the fatty stratum is a test of the richness of the milk, and it is readily but roughly ascertained by allowing the latter to rest about 12 hours in a cylindrical

graduated glass vessel. The application of gentle heat favors the rise of the cream. The percentage of cream in Europe varies considerably.* In nutritive value 1 lb. of cream represents albuminates 189 grains, fat 1869, (4·27 oz.), sugar 196 and salts 126. The analysis of cream is performed in the same manner as that of milk (313): but two grams only should be used, and the drying of the solids takes six or eight hours.

303. **Skim-milk** differs from fresh milk in containing a little less casein, and, in general, about half as much fat. The water and sugar are very slightly increased. A pound may be taken to supply 280 grains of nitrogenous, 126 of fatty food and 378 of sugar. Salts are the same as in new milk.

304. When either the cream, or milk before the cream has been removed, is churned or briskly agitated for some time, the fat diffused through the milk becomes aggregated into little solid masses separable from the liquid by straining. These constitute *butter*, to be considered hereafter. The fluid from which the butter has been removed is **butter-milk**, and is of great value as an adjunct to starchy foods deficient in nitrogen, such as rice or potatoes. In casein and salts it is equivalent to new milk; in sugar it is superior, (containing 448 grains in a pound) and it still retains a small proportion (49 grains in 1 lb.) of fat. As usually met with it is distinctly acid, owing to the conversion of more or less of its lactose into lactic acid. At a later stage the casein separates, and the whole becomes a semi-solid mass, still an agreeable and highly nutritive article of food. Fresh butter-milk has been used with great success in Germany as a food for infants.

305. When acetic or other acid is added to milk, new or skimmed, the casein and fat are precipitated and form cheese, leaving the serum or **whey**. Containing the salts and sugar of the milk, it is evidently valuable as an imperfect food; but it is little used, except as a refreshing and

* In six analyses made by Mr. Wauklyn cream ranged from 19 to 44 per cent. by weight.

nutritive drink in sickness. In some parts of Switzerland medicinal properties are attributed to it and the 'whey-cure' is in vogue.

306. The **salts** which milk contains are the sodium and potassium chlorides and phosphates, and a considerable quantity of calcium and magnesium phosphates. Casein either includes or is combined with minute quantities of the alkalies, to which its solubility is due. No sulphates, lactates or ammonium salts are found in fresh milk.

307. The foregoing pages refer more especially to the produce of the cow, but are applicable to a great extent to the milk obtained from **other animals**, the proportions only of ingredients varying, as has been seen. *Buffaloes'* milk contains a larger amount of solid matter than cows', especially of fat; and much, if not most, of the ghee and tyre or butter-milk consumed in India is prepared from it. The milk is, therefore, rich and otherwise nutritious, but the animal is a foul feeder, eating horse-dung freely and not objecting to human ordure when herbage is scarce. A buffalo, therefore, kept to supply milk or butter, should be carefully and cleanly fed and not allowed to wander. The specific gravity of the milk should not be less than 1025. *Goats'* milk also contains more solid matter (13·5 to 14 per cent.); it has less casein and sugar than cows' and somewhat more fat. Hircic acid is present and sometimes gives it an unpleasant odor. Its specific gravity should not fall below 1032. *Sheep's* milk is richer than cows' and about the same in this respect as goats'; exceeding the latter in casein, in solids and in specific gravity. *Asses'* milk contains 90·5 per cent. of water, and is far inferior to the other milks in casein and butter, exceeding them in sweetness. It approaches human milk in composition more closely than any of those yet mentioned. Its minimum specific gravity is given as 1023. It is poor as a nutrient, but valuable for invalids and infants when the digestive powers are feeble. *Mares'* milk resembles asses'. Koumiss prepared from it, by allowing it to undergo alcoholic fermentation, has been recently recommended as preventive and curative of phthisis.

308. The milk of a healthy animal properly fed will always be wholesome; but it is rarely possible to see the cattle or control their feeding, and **examination** of the milk itself, to ascertain whether it is good milk and only milk, is often necessary. Water is the only adulterant at all likely to be used in this country, and the addition will, in most cases, be detected by means of the *specific gravity*.* This with the other *physical characters*, the *reaction*, the volume of *cream* and the amount of *fat* will enable the examiner in all ordinary cases to pronounce upon the quality of the milk with sufficient accuracy for hygienic purposes.

309. As a general rule, milk, the specific gravity of which falls below 1023, has been watered and should be rejected; and the **lactometer**—a hydrometer applied to milk—is often used as a test of adulteration. It is obvious, however, that skimming the milk will raise the specific gravity, which may be again reduced by adding water. Hence the lactometer may pass as genuine watered skim-milk. It is necessary, therefore, to ascertain the amount of fat present in the sample. The volume of cream should be estimated in the manner already described; and also the percentage of fatty matter. For the latter purpose the **lactoscope** is employed, an instrument by which the degree of opacity caused by the fat-globules diffused through milk is made a measure of their amount. 100 c.c. of water have small quantities of the milk added to them until the mixture is sufficiently opaque, when placed in a glass vessel the sides of which are 0·5 c.m. apart, to render the figure of the flame of a good candle, at a distance of one meter from the eye, indistinguishable. The following table has been constructed from comparison of opacity thus determined with results of chemical analysis and shows the percentage of fat corresponding to numbers of cubic centimeters of milk which have to be added to 100 c.c. of water in order to obscure the flame†:—

* Or by evaporation and excess of percentage of solids.

† The formula from which the table has been calculated is $x = \frac{23·2}{m} + 0·23$; x being the percentage of fat, m the added number of cubic centimeters of milk.

C.c.milk.	Percentage of fat.	C.c.milk.	Percentage of fat.	C.c.milk.	Percentage of fat.
1·0	23·43	8·0	3·13	19·0	1·45
1·5	15·46	8·5	2·96	20·0	1·39
2·0	11·83	9·0	2·80	25·0	1·16
2·5	9·51	9·5	2·77	30·0	1·00
3·0	7·96	10·0	2·55	35·0	0·89
3·5	6·86	11·0	2·43	40·0	0·81
4·0	6·03	12·0	2·16	45·0	0·74
4·5	5·38	13·0	2·01	50·0	0·69
5·0	4·87	14·0	1·88	60·0	0·61
5·5	4·45	15·0	1·78	70·0	0·56
6·0	4·09	16·0	1·68	80·0	0·52
6·5	3·80	17·0	1·60	90·0	0·49
7·0	3·54	18·0	1·52	100·0	0·46
7·5	3·32				

310. The *lacto-butyrometer* is another instrument for estimating the richness of milk. It is a test-tube, divided into three decimeter-lengths, each of these being subdivided into tenths. A decimeter of the milk, to which a little potash has been added, (to keep the casein in solution), is poured in; then a decimeter of ether; then, after agitation, a decimeter of alcohol. The tube being heated in a water-bath, the butter rises to the top, its amount is read off, and its proportion calculated.

311. The **other characters** of good milk are white color, absence of deposit and of peculiarity of taste or odor. Boiling should not curdle it or otherwise alter its appearance. Its reaction should be neutral, or deviate very slightly from neutrality. Under the microscope nothing should be seen but oil-globules and a little epithelium. Much of this or pus-cells or casts of the lacteal tubules indicate disease.

312. In most cases an **examination** of milk which yields the proportions of "solids not fat" and of fat is sufficient to determine the genuineness of the sample. The standard laid down by the Society of Public Analysts requires that milk should yield, whether natural or skimmed, not less than 9 per cent. of "solids not fat" and not less than 2·5 per cent. of butter-fat. The determination of the two quantities is made thus.* Having carefully mixed the sample, by pouring it several times from one vessel to

* Wauklyn.

another, 5 c.c. are evaporated to dryness in a small platinum dish by means of a water-bath. After three hours (the water in the bath having been kept boiling), the dish is weighed and weight of its contents ascertained: which multiplied by 20, gives grams of total solids in 100 c.c. of the milk. Ether is then poured into the dish, heated to boiling and filtered. This is done three times, the filter washed with ether, the ethereal solution evaporated gently by placing the containing dish in warm water. When it becomes turbid the dish is placed upon the water-bath. The residual fat is then weighed and its proportion calculated.

313. A complete **analysis** of milk as an article of diet includes in addition to the determination of the total solids and the fat, as above, that of the *casein*, the *sugar*, and the *salts*. For the first (by which is meant the entire nitrogenous constituents) add to 50 or 100 c.c. a few drops of acetic acid, boil, add twice the volume of distilled water and leave 24 hours for complete subsidence. The precipitate consists of the **casein** and the fat. Decant and filter; wash well with boiling ether (to dissolve out the fat), dry and weigh the casein; the result will probably be too high, owing to the difficulty of completely removing the entangled fat.* The *sugar* is determined by means of a standard copper solution.† Free 50 or 60 c.c. of the milk from casein and fat (as above described), add 9 volumes of pure water, filter; drop filtrate from a graduated burette into 10 c.c. of copper solution diluted with water and boil until the mixture is colorless, (neither blue nor yellow). One-tenth of the quantity of diluted serum necessary for this is the quantity of milk whose sugar decomposes 10 c.c. of copper solution; or, which in other words, contains 0·0666 grm. of lactose; from which the sugar in any measure of the milk can be calculated.

* Mr. Wauklyn prefers to act upon the original residue, from which the fat has been removed, with strong alcohol followed by a little boiling water; thus dissolving out the sugar and the soluble salts. The casein remaining is washed into a little dish and dried on a water-bath until it ceases to lose weight. Its weight being ascertained, it is ignited and the weight of the ash (calcium phosphate) subtracted. Mr. Wauklyn recommends still more strongly the determination of casein by the albuminoid-ammonia process.

† Thus prepared. Dissolve 34·65 grms. of pure copper sulphate in 200 c.c. of distilled water. Dissolve 173 grams of sodium potassium tartrate in 480 c.c. of solution of soda sp. gr. 1·14. Mix two solutions slowly; add distilled water to one litre. 1 c. c. represents 0·005 grm. glucose, or 0·00666 grm. sucrose. The solutions keep better if preserved in separate bottles and mixed only when required for use.

314. Milk may be **preserved** in several ways. A sample of *desiccated* milk* examined by Professor Parkes contained 34·9 per cent. of casein, 22·0 of fat, 32·8 of sugar and 4·9 of salts. The powder, weighing 1502 grains, mixed with a quart of water, yielded 3·5 volumes of cream in a hundred, and the specific gravity of the milk was 1026. It became sour in 24 hours. Many varieties of *condensed* milk are prepared, the process consisting merely in partial evaporation and the addition of some sugar. They contain about 20 per cent. of water, and the relative proportions of casein, fat and salts are generally normal. They remain sweet for some months after the tins have been opened.† *Preserved* milk in tins hermetically sealed will remain good for any length of time, but the butter often separates from it and acidity sets in soon after the opening of the vessel. Milk tightly secured in a bottle while *boiling*, with a little sugar added, will keep for many months. *Sodium carbonate* or *bicarbonate* with sugar, added to milk either boiled or unboiled, preserves it for ten days or more; and *sulphurous acid* or *sodium sulphite* has a similar effect.

315. CHEESE is the casein of milk, with a variable proportion of the fat, precipitated by the action of rennet (the dried mucous membrane of the fourth stomach of the calf), pressed to remove the serum and salted to prevent decomposition. Containing a large proportion of nitrogenous aliment in a small bulk, with fat and salts, and having an agreeable flavor, it is a valuable article of food; but it is not easy of digestion, except in small quantity, and on this account it is not desirable that more than one ounce of it should form part of any meal. Larger quantities will probably pass away undigested.‡ Its liability to decomposition renders it an inconvenient article of diet for soldiers &c. in this country.

316. The precipitated casein takes with it almost all the fat which the milk contained. The richness of the milk,

* Fadouille's.

† Mr. Wauklyn found "preserved milk" to contain:—water, 20·5, fat 10·4, casein 11·0, ash 2·0, sugar (cane and milk) 56·1 per cent. by weight: "condensed milk;"—water 51·12, fat 12·11, casein 13·64, milk-sugar 20·36, ash 2·77.

‡ Cheese made from skimmed milk is a staple diet of farm laborers in the west and south of England. They eat from 3 to 6 ounces of it daily with bread.

therefore, affects powerfully the **nutritive**, as well as determines the commercial, value of the cheese; the latter, however, depending also on minute peculiarities of flavor, and on different processes of preparation. Thus *cream-cheese* is coagulated cream and contains about 50 per cent. of butter and 20 per cent. of casein. *Double gloster* and *stilton* are made from new milk to which cream has been added; *cheddar* from new milk alone. The milk which yields the commonest kinds of cheese, as *single gloster*, *cheshire*, *american* &c. has had from one-eighth to one-tenth of its cream removed before coagulation. Finally the poor cheeses of Holland, South Wales &c. are prepared from milk deprived as completely as possible of its fatty matter.

317. The **value** as a food, then, of cheese varies within limits somewhat wide. Taking cheddar as a type of new-milk cheeses, a pound of it will contain 1988 grains (4·5 oz.) of albuminate, 2177 (5 oz.) of fat and 315 of salts; that is, twice as much of the first and nearly as much of the second as fat beef or mutton, and nearly twice as much albuminate, with about ten times as much fat as lean meat, such as is usually found here. A pound of skim-milk cheese will of course exceed the other considerably in nitrogenous matter and fall below it in fat, a pound containing 3136 grains (7·2 oz.) of the former, 441 (1 oz.) of the latter, with 343 of salts.

318. Cheese, as might be inferred from its nature, is very liable to **decomposition**. Casein appears to diminish in amount and fat to increase. Lactic acid and certain fatty acids are produced. The odor becomes highly offensive, but many prefer the article in this condition, rather, however, as a condiment than as a food. Thus putrefied it can scarcely fail to be unwholesome except in small quantities, when it is said to promote digestion. Cases are reported in which fresh cheese has exhibited poisonous properties, supposed to be due to herbs in the pasture. It will be safer, therefore, to use samples of known origin and established character. Vegetable growths, as the different varieties of mould, flourish in decaying cheese, and the common acarus multiplies. Flies lay their eggs in fresh cheese, and the maggots may diminish sensibly the nutrient power of the food. Mineral poisons are sometimes used, copper sulphate, for instance, and even arsenious

oxide, to destroy the mites &c. and may be present in excess, in the rind more abundantly.

319. The only probable **adulterations** are starch, and water in excess. The former will be detected easily by means of iodine. Cheddar cheese contains about 36 per cent. of water; skim-milk cheese about 44.

320. The muscular and other tissues of animals supply food rich in nitrogenous aliment and are almost universally consumed. This kind of food will be conveniently considered under three heads—butchers' meat (which we shall call *meat*), *fish* (including molluscs and crustaceans) and *poultry*.

321. The following table shows the compositions of some ordinary kinds of meat:—

—	Cooked meat, roast, no dripping lost. Boiled assumed to be the same (Ranke).	Lean beef.	Fat beef.	Lean mutton.	Fat mutton.	Veal.	Fat pork.	Dried bacon.	Green bacon.
Nitrogenous matters ..	27·6	19·3	14·8	18·3	12·4	16·3	9·8	8·8	7·1
Fat	15·45	3·6	29·8	4·9	31·1	15·8	48·9	73·3	66·8
Salts	2·95	5·1	4·4	4·8	3·5	4·7	2·3	2·9	2·1
Water	54·00	72·0	51·0	72·0	53·0	63·0	39·0	15·0	24·0

322. Under the head of MEAT it will be sufficient to discuss *beef*, *mutton* and *pork;* but, before taking these separately, some preliminary remarks, generally applicable to all of them, have to be made. Thus the animals intended for food should be of suitable age, in sound health and in good condition; their flesh, after they have been slaughtered, should contain muscle, fat and bone in a proper state and in suitable proportions, and should be free from entozoa, perfect or embryonic, and from putrescence;

lastly, the meat should be properly cooked so as to ensure digestibility.

323. The flesh of young animals contains a larger proportion of water and is, therefore, less nutritious, weight for weight, than that of the mature. It loses more weight in cooking, especially when roasted. Old meat is tough and indigestible and deficient in fat. The proper **age** for slaughtering and the means of estimating the age differ according to the animal in question.

324. When an animal is **healthy** its movements are easy, its eyes bright, the nasal mucous membrane is moist and red, respiration and circulation are normal, the breath is sweet, the coat smooth, the excreta are natural. **Condition** depends chiefly on the amount of fat, which, when present in sufficient quantity, gives elasticity to the soft tissues and suppleness to the skin. Deficiency in this respect will be most apparent on the tubera ischii, the false ribs and the mesial line of the belly.

325. Beasts should have fasted some hours before being **killed**, because partially digested food readily putrefies. They should have rested the previous day. The blood should be removed as completely as possible, as its presence in the meat, otherwise beneficial, favors decomposition.

326. Meat should be inspected from eight to twelve hours after slaughter. The **muscles** should be firm and elastic, easily broken or torn, not pale (showing that the animal was young or diseased) or too dark (as when it is old or has died retaining the blood); section of the flesh should show no darker color than is apparent on the surface and should exhibit a marbled appearance from the ramification of streaks of fat between the muscles; the intermuscular tissue should be free from pus or other fluid and undue softness of this structure denotes incipient putrefaction. The meat should scarcely moisten the fingers, bad meat being wet, sodden and flabby: it should have little or no odor, diseased meat having a peculiar sickly smell, especially if chopped up and drenched with warm water; it should not shrink or waste much in cooking; dried at 212° F. it should not lose more than 70 to 74 per cent. of its weight, bad meat sometimes losing 80; and the juice should be distinctly acid. Decomposition in an

early stage is shown by a paler hue, a more unpleasant odor and a more friable consistence than those of fresh meat. As the process advances, the color becomes greenish and the smell offensive.* A long knifeblade pushed into the meat will encounter varying degrees of resistance and will smell disagreeably on withdrawal if decomposition is too far advanced. Meat should be cooked when it has arrived at a stage a little short of decomposition. Rations of **salt meat** are often issued to troops &c., and care should be taken that its quality and condition are good. Old meat becomes when salted tough, hard and shrivelled. If putrefaction had begun before the antiseptic was applied, the odor will reveal the fact. A cask of salt meat should be examined throughout to guard against the fraud of tainted or otherwise objectionable pieces being concealed beneath good ones. The brine also should be examined, as it is said to take up so much organic matter, if used several times, as to acquire poisonous properties.

327. **Fat** is not at all likely to be excessive in this country. Meat should show a fair amount of it, firm, healthy in appearance, free from hæmorrhagic spots. The quantity of **bone** varies with the particular joint, 20 per cent. being about the average of the whole carcase, and the proportion rarely falling below 8. The **lungs** and **liver** of slaughtered animals should be examined, to ascertain the absence of multiple abscesses and of entozoa.

328. **Cooking** is intended to coagulate the albumen and blood of the tissues; to make meat more palatable by raising its temperature and by developing flavors, and more digestible by softening tissues;† and, lastly, to destroy parasites. For the last purpose a temperature of 150° to 212° F. is necessary according to the species of entozoon. In other cases the meat should be exposed for a few minutes to a temperature of about the boiling point of water, so that a shell of firmly coagulated albumen may be formed, which will retain the juices, and afterwards the

* Meat in the earlier stage of putrescence does not appear to be dangerous as food. In later conditions irritant products of decomposition are generated and poisonous symptoms follow their ingestion. It is obviously a safe rule to avoid meat even slightly tainted.

† Meat cooked before the rigor mortis sets in is more digestible than if longer kept.

heat should not be allowed to exceed 160° F. Heat for culinary purposes may be applied to meat in three ways; either directly as in *roasting*, baking and broiling, or through the medium of water as in *boiling*, or through a small quantity of water and its own juices, as in *stewing*. Meat should never be cooked by contact with a heated solid. All these processes should be conducted slowly and at a low heat; otherwise they tend to impede rather than to favor digestion, while valuable nutrient material may be volatilized and lost.

329. When meat is **roasted** a considerable proportion of water is evaporated; some of the fat, the gelatine and extractive matters are melted out and should be restored to the diet; or their absence allowed for, in estimating its value, if they are removed. Roast meat is less digestible than boiled or stewed: and the action of a high temperature on the superficial fat sometimes produces acrolein and fatty acids which are apt to distress weak digestive organs. Hence all baked or roasted meat disagrees with some persons of weak digestion; and frying or grilling is still more likely to generate indigestible products.

330. The most economical of these processes is **boiling**, and boiled meats, though less savory are more digestible. It is, however, unsuited to the flesh of young animals, which includes much gelatine and soluble albumen. The water should be boiling for five minutes and then kept at a temperature not exceeding 170° F. A large proportion of valuable food, salts more especially, passes out into the water; and 30 per cent. of the solid matter of the liquid in which meat has been boiled has been found to consist of nutrient salts. It is obviously desirable, therefore, that this broth should be utilized as food. When meat is destructively boiled, for the purpose of extracting from it all its soluble material, it should be cut or rasped as fine as possible, put into cold water with a little muriatic acid and slowly boiled.*

331. **Stewing** is a process intermediate between the other two. The meat is generally cut up and vegetables

* To make strong "beef-tea," for example, mince one pound of beef and bray in stone mortar with 12 drops of hydrochloric acid, add 1¼ pint of cold water; boil slowly for half an hour; give one rapid boil and strain through a cloth. Almost every thing will pass through the strainer.

often added. Its own juices with a little water maintain an even temperature, which should be low. The loss of weight need not exceed 20 per cent., which is chiefly due to loss of water. Meat thus prepared is digestible and little of its nutritive matter has been wasted.

332. The **loss** of weight per cent. due to cooking, in some ordinary cases, is thus stated by Dr. Letheby :—

——	Boiling.	Baking.	Roasting
Beef generally	20	29	31
Mutton do.	20	31	35
Legs of mutton	20	32	33
Shoulders of do.	24	32	34
Loins of do.	30	33	36
Necks of do.	25	32	34
Average of all	23	31	34

Some samples of American pork lose as much as 50 per cent. of their weight in boiling.

333. Three conditions are necessary to putrefaction, namely, moisture, atmospheric air and a temperature between 40° and 200° F. All preservative processes must depend upon the exclusion of these conditions or on the use of chemical agents. Of the many plans which have been adopted for the **preservation** of meat, *salting* is the commonest and in some sense the most economical. The meat is either kept in vessels containing a saturated solution of common salt, or such a solution is forced into the mass by means of a suitable syringe. This method is effectual but is attended with considerable disadvantages. The fibre of the meat is hardened, so that slow and careful boiling is necessary to prepare it for food, and after cooking it remains less digestible than the fresh meat. Vinegar eaten with it as a condiment probably obviates in some degree the latter disadvantage. The nutrient salts of the meat pass out into the brine and are replaced by the latter, so that sodium chloride is present in excess and other salts deficient. Still more of these are lost in slow boiling, necessary not only to make the meat digestible, but also to remove as much as possible of the salt; while, owing to excess of chloride,

the meat liquor is unfit for use.* *Partially cooked* meat keeps longer than uncooked, but the flavor is injured. Meat decomposes less readily in an atmosphere of *sulphurous acid*, or covered with *charcoal* or sugar, with strong *acetic* or with weak *carbolic* acid. It may be kept sweet for years in *tins*, either by excluding atmospheric air completely, or removing its oxygen by means of sodium sulphite, or by substituting for it a mixture of nitrogen and sulphurous acid; heat being employed in all these cases, so that the meat is partially or completely cooked. Meat more or less fully *dried* resists decomposition and may be mixed with antiseptics or condiments, or with other articles of food as flour, starch or fat. Various *extracts* are prepared which contain the salts and the soluble albuminates of the meat, but these are rather stimulant medicines than foods, they are incapable alone of sustaining life and health, they are only to be used when meat itself is unattainable, and their employment requires caution, because excess is easy and injurious.†

334. The **advantages** of meat generally as an article of food are its composition, containing as it does albuminates,

* The following table shows the difference in composition of fresh and salt beef:—

—	Fresh.	Salted
Water	75·90	49·11
Solids	24·10	50·89
	100·00	100·00
Nitrogen *per cent.* ..	3·031	4·631
Phosphoric acid do. ..	0·229	0·618

The brine of American salted beef has been found to contain 12·300 grms. per litre of albumen, 34·050 of other organic matters, 4·812 of phosphoric acid, 290·071 of sodium chloride, and 36·577 of other saline matters. Nitrogen amounted to 2·669 per cent. of dry extract.

† Lean meat contains about 25 per cent. of solid matter, the rest being water. Of the former from 7 to 10 per cent. is soluble in cold water and rather more than half of this is coagulable by heat. Hence, if a cold infusion of meat is boiled, it retains in solution about 3 or 4 per cent. of the meat. Such a solution evaporated to dryness

fat and valuable mineral constituents (potassium chloride, phosphate and lactate, with iron and others); its having these in a state of combination resembling that of the human tissues; its being easily cooked; and easily digested, more easily, probably than any vegetable food. Its great and obvious disadvantage is the absence of carbo-hydrates, which are, therefore, in practice supplied by the addition of bread, rice or potatoes. The nutrient values of the flesh of different animals differ only in the proportion of fat and by different degrees of digestibility. For regular use, beef and mutton are the best animal food, venison, fish, game and poultry being occasionally introduced for the sake of variety.

335. The general signs of **health** in animals intended for conversion into BEEF have been already given. Whether certain diseases to which cattle are liable render their flesh unfit for human food or not is still undecided. It will be a safe rule to sanction the slaughter of no animal for this purpose which does not appear to be perfectly sound or to be suffering only from the effects of surgical accident. Emergencies may arise, as in sieges for instance, in which

yields *Extractum Carnis*. It consists principally, therefore, of certain acids, creatine, creatinine &c. with the soluble saline constituents of the meat. It contains from 41 to 60 per cent. of water, from 22 to 41 of organic matter and from 8 to 16 of salts. Its reaction should be always acid. It contains no albumen, fat or gluten, and represents merely soup or beef-tea made from meat. To use it as a nutrient, therefore, it must be mixed with beans or pease or some other nitrogenous food. Its physiological action, used alone, is restorative rather than nutritive and more analogous to that of alkaloidal beverages than of foods proper. The following table gives the percentage composition of some of the extracts known in commerce:—

—	Liebig's Company.		Tooth, Sydney.	French Company, S. America.	White-head.	Twenty-man.
Water	18·56	16·00	17·06	16·50	24·49	20·81
Extractive soluble in alcohol ..	45·43	53·00	51·28	28·00	22·08	13·37
Do. insoluble ..	13·93	13·00	10·57	46·00	44·47	59·10
Mineral matter ..	22·08	18·00	21·09	9·50	8·96	6·72

necessity will demand some relaxation of this rule and discrimination with respect to the disease, but such cases are obviously exceptional. Epizootics with their symptoms and their probable effect upon the flesh of the subjects will be considered hereafter.

336. The **age** of the bullock or cow should be between three and eight years. It may be known to a certain extent by the rings on the horns and with sufficient certainty by the teeth. Each ring represents a year up to the fifth; but after this age the first three rings become obliterated. An animal, all whose horn-rings have disappeared, is probably eight years old *at least*. In the fourth year the permanent teeth are generally in their places; in the fifth the edges of the incisors are slightly worn down; at six years the first molars are worn to a level with the incisors; at eight they are considerably worn; when the upper surface of the teeth show a mark, either square or round, the animal is too old for good beef.

337. The **weight** of meat obtainable from a bullock may be roughly ascertained before death by measurement. Length from behind scapula to root of tail and girth behind scapulæ, multiplied together and the product by 3·36 give the weight in pounds; and 60 per cent. of this may be counted as beef; the head, feet and internal viscera (except the kidneys) not being included. The weight of an Indian bullock rarely exceeds 150 lbs.

338. **Measles** in beef, that is, its special *Cysticercus*, may produce the *Tænia mediocanellata* in those who eat it. The small round bodies are readily visible and should be sought for in the psoas muscle more especially. When they are very numerous the meat *crackles* when cut. Efficient cooking destroys their vitality, which is unaffected by salting.

339. The nutrient **value** of the muscles and other parts of the bullock will be best shown by a statement of the quantity of each alimentary principle in one pound, as shown in the following table :—

	Albuminate, grains.	Fat, grains.	Salts, grains.
Lean beef	1,351	252	357
Fat do.	1,036	2,086	308
Liver	1,323	287	210
Tripe	924	1,148	168
Veal	1,155	1,106	329

340. **Bone** is not by any means destitute of nutritive power. To obtain as much aliment as possible from bones they should be crushed small, boiled for 15 minutes (in an iron vessel) and the fat skimmed off when cold. They should then be ground and boiled in the same water, made up to ten times their weight, until the bulk is reduced one-half. The jelly resulting is a very incomplete nutrient. Joints are on the whole less valuable as food in proportion to their amount of bone. The neck and brisket of beef include about 10 per cent.; shins and legs from 33 to 50. The most economical pieces of the animal are the round, the rump and the brisket.

341. A sheep should be from 18 months to 5 years old for **mutton.** At the former period it will have four or five pairs of permanent molars: after the latter the teeth will begin to show wear. An Indian sheep weighs from 25 to 35 pounds, and gives 60 per cent. of meat. The *Strongylus filaria* is often found in the lung, causing phthisis, and the *Distoma hepaticum* in the liver. The animal is subject to many diseases, easily recognizable during life. A pound of lean mutton yields 1,281 grains of albuminate, 343 of fat and 336 of salts; the corresponding numbers for fat meat being 868, 2,177 and 245 respectively. The leg is a more economical joint than the shoulder. Mutton-broth is intermediate in strength between chicken-broth and beef-tea. *Goats'* flesh is inferior to sheep's in flavor and probably in proportion of fat. *Venison* is no less nutritious than beef or mutton and is generally more easily digested. It contains more blood than regularly slaughtered meats.

342. **Pork,** bacon and ham are, as a general rule, nutritious and wholesome articles of food. In this country, however, where pigs are the most efficient scavengers,

there is a well-grounded prejudice against their flesh. Diarrhœa is said to be sometimes caused by eating pork, although the animal appeared when slaughtered to be in perfect health. Careful and thorough cooking is necessary in order to destroy the entozoa with which this animal is more liable to be infested than the ox or the sheep and which are capable of setting up disagreeable, dangerous and even fatal diseases in those who swallow them. Thoroughly cooked flesh, however, of carefully and cleanly fed pigs is an excellent food, exceeding mutton and beef in proportion of fat and, therefore, suitable for use with poultry or rabbits, which are deficient in that particular. Black-pudding, prepared from pigs' blood mixed with goats' and fat contains 11 per cent. of nitrogenous aliment. A full-grown pig weighs about 150 lbs., of which from 75 to 80 per cent. is capable of use as food. The leg of pork, as of mutton, is more nutritive, weight for weight, than the shoulder.

343. The **nutritive value** of pork &c., and especially their abundance of fatty food, will be apparent from the following table :—

	Albuminate, grains in lb.	Fat, grs. in lb.	Salts, grains in lb.
Fat pork	686	3,423	161
Green bacon	497	4,676	147
Dried do.	616	5,131	203

344. These foods contain little water and lose little weight, from 10 to 15 per cent., in cooking; with the exception of some kinds of American bacon which, derived from animals fed upon oil-cake or oily nuts, contain a more diffluent fat than ordinary specimens, much of which melts out in cooking. Nitrogenous food, it will be observed, is comparatively deficient. Hence pease in some form is often added to pork and bacon to supply the want.

345. Two **parasitic** diseases are communicable by pork to those who eat it. The *Cysticercus cellulosæ* is often present in the muscles in great numbers, especially immediately beneath the skin, which is elevated into prominences popularly called "measles," which are also plainly visible in the flesh after death. The inner surfaces of the eyelids

and the under surface of the tongue exhibit these little protuberances in measly pigs. The necks of animals thus diseased are sometimes thickened. In the intestinal tract these entozoa become developed into the *Tænia solium*, unless their vitality is destroyed by careful cooking or smoke-drying at a considerable temperature. Salting is powerless to destroy them. The *Trichina spiralis* is the immature condition of a minute thread-worm which inhabits the intestines of several species of animals. The embryos are hatched in the bowel, through the wall of which they bore and disperse themselves through the muscles, causing a severely painful and not unfrequently fatal disease called trichiniasis. About a fortnight after birth the trichinæ become fully developed and are encapsuled in calcareous matter in the muscles, in which condition they may remain inert for years. When meat containing these encysted trichinæ is swallowed the entozoa are liberated in the intestinal tract to produce innumerable embryos, to act as above described. If encapsuled, the round specks will be visible to the naked eye; if not, a low-power microscope will suffice for their detection. A thin slice of the suspected flesh (the muscles of the eye being a probable habitat) is allowed to remain for a few minutes in liquor potassæ diluted with eight parts of water; the muscle will become clear and the trichina visible. A drop of dilute hydrochloric acid will dissolve the capsule, if present, and disclose the worm coiled upon itself. They are sometimes detectable during life in muscle removed from beneath the tongue. The coiled parasite should be distinctly seen, or psorospermia (which do not appear to be hurtful to those who eat flesh infested with them, though they cause illness to the hosts) may be mistaken for them. Nothing but thorough cooking can be relied upon to render meat containing trichinæ wholesome. Fresh meat retaining a red color is insufficiently cooked. Under no circumstances should pork or bacon or ham or sausages be eaten raw.

346. Sausages are theoretically made with pork; but practically the large amount of spices which enters into their composition enables very miscellaneous and often objectionable substances to be disguised under this form of food. Putrid or semi-putrid meat, the flesh of animals which have died of disease or of healthy animals not usually considered

fit for human food, pork infested with cysticerci or trichinæ, may be thus employed. Whether from the use of materials primarily poisonous, or from the development, subsequently to manufacture, of a poisonous result of secondary putrefaction, very serious consequences have followed the eating of sausages; but the noxious element has not been isolated. Sausages, therefore, should be known to be composed of innocent materials, should not be kept too long, and should be thoroughly and carefully cooked.

347. FISH is generally a digestible and wholesome article of diet, but is not fitted to be exclusively or principally used as food. It is valuable as an occasional addition to or substitute for other aliments, but a scorbutic condition is likely to follow a diet containing fish alone or in excess. Caution is necessary in eating unknown fishes, especially in the tropics, some being poisonous, either always or at certain seasons, producing severe gastro-intestinal irritation followed by great prostration. Putrid fish is eaten by Burmese and Chinese without apparent ill-effect, but the example is not desirable to follow. The introduction of distomata into the body is supposed to be due to the eating of uncooked fish. Boiled in sea-water or hard-water fish is firmer than if the water be soft. As a general rule (with many important exceptions) frying is a better method of cooking than boiling. There is very great variety in flavor, in proportion of bone and in digestibility; but the division into *white* fish and *red* fish will be sufficient for our purpose.

348. The sole, turbot, flounder and whiting are examples of **white fish.** This class of food contains 18 per cent. of nitrogenous matter, 3 of fat and 1 of salts. It is, therefore, deficient in fat and requires the addition of butter or oil. A pound of white fish contains 1,267 grains of albuminate, 203 of fat and 7 of salts. In the first, therefore, it is about equal in nutritive value to lean beef, but it is inferior in the other respects.

349. **Red fish** includes the salmon, trout, mackarel, eel, herring, sardine and most fresh-water fishes. These include from 5 to 14 per cent. of fat, and are superior as nutrients to the other class. A pound of salmon contains 1,127 grains of nitrogenous food, 385 of fat and 98 of salts.

350. Fish containing a large proportion of water, the nutritive value of a given weight is much increased by drying. **Dried** fish contains somewhat less than double the nourishment of the fresh food ; and in dietaries, therefore, it is usual to count one ounce of the former as equivalent to two of the latter. In small quantities salt-fish is a useful condiment.

351. **Shell-fish** differ little in nutritive value, but very considerably in digestibility. Some of them are invariably poisonous to some constitutions, producing violent gastric, intestinal and even cerebral disturbance. All of them are liable to become dangerous at certain seasons. The oyster is probably the most digestible of the common molluscs. It contains 14 per cent. of nitrogenous matter, 1·5 of fat and 2 of salts. The corresponding numbers for the mussel are 11·7, 2·4 and 2·7.

352. The **crustaceans**, as the lobster, crab, cray-fish and prawn, contain much nutrient material, but are indigestible to many and poisonous to some. It has been supposed that prawns inhabiting foul rivers, abounding in putrid animal and vegetable remains, are more unwholesome than others, but there is no reason to believe that the animals take up anything from their food likely to injure those who eat them. The lobster contains from 10·2 to 12·1 per cent. of nitrogenous food, fat 1·2 to 1·4, salts 1·8.

353. Poultry proper, fowls, turkeys &c., with which rabbits may be included, supply highly nitrogenous food, in this respect exceeding beef; but they are deficient both in fat and in salts. Accordingly it is customary to combine fatty and saline foods, as bacon or tongue, with them. A pound of this kind of food contains 1,470 grains of albuminates, 266 of fat and 84 of salts. Of the three ordinary broths, that prepared from chicken is the strongest. The flesh of geese and ducks is much superior in fat, but inferior in digestibility. The dark flesh of game-birds and of hares is likely also to be difficult of digestion and requires careful cooking.

354. Eggs afford a food highly nitrogenous but deficient in carbon, and, therefore, requiring the addition of a starchy substance (as rice or bread) or a fatty substance (as bacon). The weight of the egg of the ordinary Indian

fowl is about 600 grains,* of which 10 per cent. may be deducted for the inedible shell. The white weighs about twice as much as the yolk. The *white* consists of 78 per cent. water, 20·4 of albuminate and 1·6 of salts; no fat. The *yolk* contains abundance of fat, amounting to 30·7 per cent., 16 per cent. of albuminate and 1·3 of salts, besides 52 per cent. of water. The contents taken together yield 14 per cent. of nitrogenous food, 10·5 of fat and 1·5 of salts. Their digestibility is somewhat diminished by partial, and considerably impaired by complete, coagulation of the albumen in cooking.

355. A pound of eggs, such as are ordinarily met with in this country (say 13, allowing 10 per cent. for shell) will have, according to the proportions given above, the following **nutritive value**:—

—	Albuminates, grs.	Fat, grs.	Salts, grs.
White	1,428	...	112
Yolk	1,120	2,149	91
Both together	980	735	105

356. Eggs lose translucency and weight when they are kept too long. A **good egg** is slightly translucent throughout and sinks in a 10 per cent. solution of common salt. A bad egg floats in fresh water and a doubtful one in the above solution.

357. Eggs may be **preserved** for a considerable time by any means which renders the shell impermeable by air, as covering it with gum, or grease, or a solution of wax in sweet oil, or packing the eggs lightly in saw-dust, or putting them into lime-water to which a little cream of tartar has been added. Partial boiling, so as to coagulate a thin external layer of albumen, has a shorter preservative effect.

358. Coming now to vegetable foods containing considerable quantities of albuminate we have two great groups—the CEREALS and the pulses or leguminosæ. Of the

* The average weight of 12 eggs was 608 grs., the maximum was 700 and the minimum 550.

former, *rice* and *wheat* are first in importance, *maize*, *oats* and *barley* will require brief notice also, and the Indian *dry grains* will be next discussed.

359. **Rice** forms the staple food of a very large proportion of mankind. It is a valuable food abounding in starch, not destitute of albuminates and salts, easily grown, easily cooked and easily digested. It is deficient in nitrogenous aliment, being in this respect the lowest of the cereals; hence it demands the addition of meat or fish or leguminous seeds, of milk or buttermilk. It is deficient in fat, and, therefore, requires butter, ghee or other fat. Salts are also ill-provided, and must be supplied by other foods ; hence a dietary consisting mainly of rice requires a more generous salt ration than one of wheat or millet. It is insipid and needs the aid of condiments.

360. There are innumerable varieties of the rice-plant and considerable variation in **nutritive value**, the nitrogenous matter, for instance, ranging from 3 to 7·5 per cent. of the undried grain. Payen's analysis of a sample of *dried* rice gives nitrogenous matter 7·5, starch &c. 89·6, fat 0·8, cellulose 1·1, salts 0·9. Letheby states the composition thus:—nitrogenous 6·3, carbo-hydrates 79·5, fat 0·7, salts 0·5, water 13·0. If we take 6·3 as a fair percentage of albuminate in average rice, a pound will contain 441 grains, while the starch will be 5,437, the fat 49, sugar 28, and salts (potassium, magnesium, phosphoric acid &c.) 35 grains.

361. Rice should have been kept at least six months before it is used as **food**, otherwise indigestion and diarrhœa are likely to follow; nor does it boil well, the grains adhering together in lumps. The grains should be of average size, free from epiphytic* spots and from holes made by insects; they should not break readily on pressure. Paddy is partially boiled and then dried before it comes into the grain-market, except in the case of what is called "table rice" (used by Brahmins and Europeans), which has not undergone this process. Rice is prepared for food by slow boiling or steaming. Its flour may be made into cakes, but, unless mixed with wheaten flour, is incapable of preparation as bread.

* There is some reason to suspect that the obscure disease called beri-beri is attributable to diseased rice.

362. Next to rice, **wheat** is probably the grain which is most extensively used as food by man. Like the other cereals its seed contains but little water, (not more than 15 per cent.), while albuminates of various kinds constitute about 10 per cent. of its weight (gluten ranging from 9 to 15 per cent.) and it is rich in digestible carbo-hydrates and in valuable salts, chiefly phosphates of magnesium and potassium. On the other hand it is deficient in fat, and, therefore, requires, when it is the staple food, the addition of butter or ghee if made into bread or cakes and of suet &c. if eaten in the shape of puddings. It is deficient also in the anti-scorbutic salts. The grains should be of good size and weight, free from odor, spots and holes. Insects and fungi should be absent. When ground it consists of two separable substances—the husk called the *bran* and the inner starchy portion called *flour*. The mixture of the two is *meal*. 504 lbs. of wheat should give 392 lbs. of flour.

363. The **bran** consists of the outer silicious coat, which is altogether innutritious, and should in all cases be removed, as being not only useless but irritant; and of the inner coat which contains a large proportion both of nitrogenous food and of salts. Bran bears to flour a proportion varying with the quality of the wheat and other circumstances. One to four is a fair average. Flour, except the finest kinds (including the *rolong* or soojee, of which white bread is made in India), contains a variable proportion of bran and its nutrient power is thereby increased.

364. The **nutritive value** of the bran, including all the coats, will be understood from the following figures:—1 pound contains 721 grains of water, 874 of albuminates, 197 of fat, 5,068 of carbo-hydrates (nearly two-thirds *cellulose*) and 176 of salts. It must be remembered, however, that the cellulose is useless and the whole of the silicious outer covering injurious, so that at least 50 per cent. of the indigestible bran is valueless for nutrition. Most nutriment is obtained from wheat when the bran of the inner coverings, ground as fine as possible, is left with the flour; or when water, in which the bran has been steeped or boiled, is added to the flour during its preparation as food. The outer bran being coarser than the inner is readily separated by sifting.

365. A pound of bran-free flour may be taken to contain on an average 756 grains of albuminates, 14 of fat, 4,641

of starch &c., 294 of sugar and 119 of salts. When gluten abounds, as in our Indian wheat, the heart of the grain forms a granular powder, corresponding to the "first flour" of Europe and called "rolong" or soojee here.* This form of flour is either made into ordinary bread or boiled slowly in milk or water and eaten with milk and sugar. In the latter form it is, if carefully boiled, a wholesome and nutritious food for children. *Semola* is prepared by washing away much of the starch of flour; it contains about 48 per cent. of albuminates. *Macaroni* and *vermicelli* are made from flour rich in gluten; and contain, weight for weight, two or three times as much nitrogenous aliment as good wheaten bread; to which, however, they are inferior in digestibility.

366. The **examination** of flour should be *physical* to ascertain its age and condition; *chemical* to learn its nutritive power and detect certain adulterations; and *microscopical* to test its genuineness and its freedom from minute animal and vegetable organisms.

367. The **physical** characters of good flour are whiteness, tinged with brown in proportion to the amount of bran allowed to remain, or with red if the wheat have been of the "red" variety, but very faintly, if at all, with yellow; the starch grains should not stick together in lumps, though there will be sufficient adhesiveness to form friable masses on pressure, or to cause adherence to a surface against which the flour is thrown; the dough should be somewhat tough and capable of being drawn into strings like macaroni; the reaction will be faintly acid, but acidity perceptible to the taste shows excess of lactic or acetic acid and unfitness for use; it should be free from mouldy or other abnormal odor. Flour too old for use will be yellow, gritty and sour.

368. The **chemical** examination determines the proportion of water, of gluten and of mineral constituents, as well as the nature of the last. The *water* is estimated by drying about a gram in a water-bath, and ascertaining the loss of weight. The percentage should be from 14 to 17 and in kiln-dried flours (which are less liable to acidification than others) the proportion will be as low as 10 per cent. *Gluten* is the principal albuminate of wheat and its amount is a good measure of the nutritive value of a sample of flour. Take about 10 grams and make it into dough with a little water by means of a glass rod, in a

* It corresponds to the *Semolina* of Europe.

weighed dish. After it has stood for half an hour pour on fresh water, stir with the rod and pour off the water; repeat this process until all the starch is washed away from the gluten, as shown by the clearness of the water. Dry and weigh. The proportion varies from 8 to 15 per cent. The wheat of Southern Europe and of India is rich in gluten, and 10 or 12 per cent. may be expected in ordinary Indian samples. No flour containing less than 8 should be used for bread. The gluten should be capable of being readily drawn out into thin threads like vermicelli; and increase of volume of undried gluten, exposed to a temperature of 210° C. in an oil-bath, is proportionate to the value of the flour. It increases from two to six times. Incinerate about 10 grams thoroughly and weigh the *ash*. It should not exceed 2 per cent. or fall below 0·8. If it is above the major limit adulteration with some mineral substance has been practised. Effervescence on addition of dilute hydrochloric acid, shows the presence of a carbonate; and lime or magnesia can be detected and estimated as before described (158), (167). If there is no effervescence calcium sulphate may have been the adulterant and will be detected by the presence of calcium and excess of sulphuric acid, which in pure flour is present only in traces. Clay will be insoluble in water and acids. A good method has been suggested for roughly ascertaining whether a large quantity of mineral impurity has been added to flour. When some of it is shaken with chloroform the flour itself floats, the adulterating substance falls.

369. The water with which the gluten has been washed contains the starch of the flour in suspension, the soluble albumens, the sugar and the dextrine in solution. The *starch* can be separated by filtration or decantation, dried and weighed. The *albumen* will be precipitated by boiling with nitric acid, after concentration of the solution. Evaporation to dryness gives the remaining carbo-hydrates.

370. Under the **microscope** the fragments of husk will be readily distinguishable from the starch-grains and these from other starches introduced for adulteration. The wheat starch-grains vary greatly in size, and are often present only as exceedingly small round particles and round, oval or lenticular granules, 0·002 inch or more in diameter, intermediate sizes being absent. Concentric lines are few and faint; the hilum central, if visible at all. The granules of *potato-starch* are pyriform, with concentric rings distinct and a hilum at the smaller end. A weak solution of potash (liquor potassæ ten times diluted) swells them out, but scarcely affects the true wheat-granules. Both the husk and the starch-grains of *maize* are too characteristic to be mistaken, the latter being very small and polygonal. The granules of *leguminosæ* are oval, reniform or slightly pyriform, without hilum or rings, but having a longitudinal depression or cleft not extending through the whole length. The rice husk is too peculiar to escape observation, and the starch-granules are polygonal like those of maize, but much smaller. Lastly, the starch-granules of the *millets* or common Indian dry grains are very small and nearly uniform in size, while the envelopes present highly characteristic appearances.

371. Low vegetable and animal **organisms** are also detected by the microscope. Some *fungi* are found, and their presence is supposed to be injurious. The *Acarus farinæ* is not uncommonly found both in

the corn and in the flour. A solitary specimen may be found even in good flour, but its presence shows that changes unfavorable to the nutrient power of the food are going on and examinations should be periodically made. *Vibrios* are met with only in flour undergoing decomposition.*

372. The efficient **cooking** of flour essentially consists in such application of heat and moisture as will ensure the thorough rupture of the starch cells. Water alone will effect this object if supplied in sufficient quantity, but neither bread nor the ordinary preparations of wheat-flour contain water enough for this purpose without the aid of heat. As secondary effects of increased temperature albumen is coagulated and some of the starch converted into dextrine. "Farinaceous foods" consist of baked flour, the starch being converted into dextrine by a temperature of 400°–450° F. The same may be effected by boiling flour in a cloth for some hours, which grated and mixed with milk forms an excellent food for children. Liebig's Food contains malt and other substances besides flour,† so that its proportion of nitrogenous to carbonaceous aliment is 1 : 3·8. Besides preparations of these kinds, flour is made into *cakes* of various sorts, into *biscuit* and into *bread*.

373. The commonest form of **cake** is what is called in India the *chupatty*, and in this form wheaten flour forms the staple food of large populations in the North-west. It consists generally of flour, water and salt alone; milk, butter or ghee being sometimes added. It is nutritious and wholesome when thoroughly baked, but the temperature should not exceed 212° F. When fat of any kind is added to flour, (and we have seen that the addition before or after cooking is indispensable), as in the preparation of the different sorts of *pastry*, care should be taken that the paste should consist of thin layers; otherwise the fat will protect the starch of the flour from the solvent action of

* Ergot is a rare but dangerous impurity in wheat-flour. It is detected by shaking some of the flour in a mixture of one part chloroform with six parts alcohol. It is the lightest substance present and floats on the surface of the fluid as a scum of dark brown particles.

† An ounce of wheat-flour is mixed with 10 ounces of milk, boiled for three or four minutes and allowed to cool to 90° F.; an ounce of powdered malt, with 15 grains of potassium bicarbonate and 2 ounces of water, is added: the whole is stirred and allowed to stand for 90 minutes at a temperature of 100° F.; it is then boiled gently for a few minutes and strained.

the saliva, which is incapable of acting upon the fat. Inattention to this precaution is the cause of the frequent unwholesomeness of this kind of food, which, if properly prepared, should be digestible and nutritious.

374. Flour, with or without bran, mixed with water and baked at a high temperature, constitutes **biscuit.** It contains less water than cakes or bread, and, therefore, has theoretically a higher nutritive value in the proportion of 4 to 3; but, in practice, it is not found capable of replacing the latter as a staple article of diet, except temporarily. It appears to tax unduly the masticatory and digestive powers, owing probably to the closeness of its texture. Addition of eggs, sugar and butter improves the digestibility of biscuit. Some kinds are finely vesiculated by means of ammonium carbonate and an acid and are easy of digestion. A pound of ordinary biscuit contains 1,050 grains (2·4 oz.) of albuminates, 91 fat, 133 sugar and about 5,250 grains (12 oz.) of other carbohydrates. Good biscuit is hard, of light yellow color (unless there be intermixture of bran) and free from insects.

375. When the dough is rendered spongy in texture by the passage of air or carbonic acid gas through it, dividing it into minute cavities separated by thin partitions, **bread** is formed. Flour containing 8 to 10 per cent. of gluten is necessary for this purpose, the required vesiculation not being effected by the permeating gas when gluten is deficient. Mastication, complete contact with saliva and consequently effective digestion are promoted by this mode of preparing flour, but any chemical changes which may take place are accidental and secondary to the main object of minute sub-division. To secure good bread there should be (1) good flour, containing a sufficient proportion of gluten; (2) good yeast or its equivalent; (3) thorough intermixture of the ingredients by kneading; (4) salt enough to regulate the fermentative process and impart flavor; (5) a temperature sufficiently high to convert starch into dextrine. Baking will be more satisfactory if loaves are separate in the oven.

376. The **nutritive value** of bread is high. It is capable of being used as the staple article of diet for an indefinite period without producing distaste. It is readily prepared and easily digested. On the other hand, it is

deficient in fat; and in salts if the whole of the bran has been removed. It differs from the other preparations of wheaten flour in containing a larger proportion (more than twice as much) of water; but it is probably, weight for weight, a more nutritious food than either, owing to its greater digestibility. A pound of average bread may be taken to contain 561 grains (1·3 oz.) of nitrogenous aliment, 112 of fat, 252 of sugar and 3,318 (7·6 oz.) of starch, &c.

377. The flour being suitable and the dough skilfully prepared, (so as to be neither so tough as to prevent the free passage of gas through it nor so soft as to admit of its immediate escape) the vesiculation or **raising** of the bread may be effected either by forcing air through it from without or by causing the generation of carbonic acid gas in the dough itself. The former method requiring costly machinery is only practicable on the great scale and is scarcely suitable to this country except for the supply of large European garrisons. The bread is somewhat less agreeable to the taste than that made otherwise, and it has a tendency to become disagreeably dry; but the method of manufacture obviates the unpleasant necessity for contact between the dough and the workmen's hands or feet.

378. Carbonic acid is usually disengaged in dough by the process of alcoholic fermentation, of which it is one of the primary products. Fresh yeast* from a brewery, or yeast in powder, dried without destroying its vitality, or toddy undergoing vinous fermentation, mixed intimately with the dough and aided by heat, sets up fermentation in the sugar of the flour and the gas is disengaged throughout the mass. The second of these methods is best adapted to our circumstances. Toddy is not always obtainable fresh and not unfrequently it has to be used when the acetous fermentation has begun; and the bread is sour. It is important to prevent the chemical changes essential to these methods from proceeding too far, as organic acids may be produced and the gas is generated at the expense of the carbo-hydrates of the flour. It is sometimes with a view to check these transformations that alum is added to flour.

* Potatoes are generally used in preparing the ferment for bread. Some mealy tubers are boiled in water, mashed, and when cooled to 80° F. mixed with yeast and flour at a temperature of 80° to 90° F.

379. The use of **baking-powders** supplies the needful carbonic acid without diminishing the nutrient properties of the flour. They consist of an alkaline carbonate—sodium or ammonium—mixed with an acid, as tartaric or citric.* The powder is carefully diffused, with the salt, through the flour; and when water is added and the dough formed carbonic acid is disengaged throughout the mass. Sometimes the carbonate only is added to the flour and an acid, one of those named above, or phosphoric or hydrochloric† or lactic (in the form of sour milk) is mixed with the water. The disadvantages of this method are the difficulty of equably diffusing the powder through the dough and the risk of a disagreeable flavor being communicated to the bread by the salt resulting from the chemical decomposition which generates the gas. Dough thus prepared must be baked at once.

380. **Good bread** should contain nothing but flour (with or without the inner bran finely ground), salt, a little sugar, and water. Milk may be added if the bread is to be consumed immediately, otherwise it becomes acid soon. The water should not exceed 45 per cent., but 33 per cent. is quite enough. Excess of water diminishes the nutritive value of the bread and renders it more liable to fungous organisms. The crust of the baked loaf should not fall below 30 per cent. of the weight; it should be firm and not over-baked. The vesication of the crumb should be perfect: the cavities small, regular and present in every part; their walls soft. The color should be nearly white if pure flour only were used; brown in proportion to the admixture of bran: a yellow hue denoting the use of old and changing flour. No acidity should be tasted, even when a piece of the bread is held for a considerable time in the mouth; this would imply acid flour or sour ferment. The loaf should be specifically light; heavy, sodden bread being indigestible and indicating bad flour, bad yeast or unskilful preparation.

381. **Further examination** of bread may be sometimes desirable to ascertain the proportion of water or the amount of acid which it

---

* For example, 1 part of tartaric acid with 1½ parts of sodium carbonate and 4 of potato-flour or dry starch. "German yeast" is the dry residue of yeast obtained from the fermentation of rye in the manufacture of "hollands."

† This acid used with sodium carbonate supplies sodium chloride to the bread as well as carbonic acid.

contains and to detect adulterations. A known quantity being partially dried, powdered and exposed to a temperature of about 240° F., the loss of weight represents the *water*. The *acidity* may be known by noting how much of an alkaline solution of known strength is required to neutralize some distilled water in which a known weight of the sample, slightly dried and powdered, has been steeped for 24 hours. Comparison should be made with the result of a similar experiment on bread of recognized soundness.

382. The only **adulterants** requiring to be noticed are rice, millets and alum. *Rice* absorbs much water, making the bread heavy, closer in texture and imperfectly vesiculated. The *dry grains*, even in small amount, darken the bread, and the microscope may be useful in detecting their presence. *Alum* is added to check excess of fermentation and to enable old and changing flour to be made into bread. It whitens bread also. Its presence, therefore, is always suspicious. If distilled water in which half a pound of bread has been steeped is filtered and gives no precipitate on the addition of a few drops of hydrochloric acid and solution of barium chloride, alum cannot have been present. A sulphate in the water or in the salt with which the bread has been made will give a precipitate; these ingredients should, therefore, if possible, be examined before inferring the presence of alum from the formation of a precipitate. The log-wood test is relied upon with confidence by some chemists. The bread-crumb is soaked for six or seven minutes in a tincture of log-wood, alkaline by ammonium carbonate, and squeezed. Two grains of alum in the pound will give a light-blue color, greater quantities darker blues up to 8 grains when gradations cease to be distinguishable.

383. The **ill-effects** which may follow the use of unwholesome bread arise either from bad flour, or from improper preparation or from the addition of adulterants, as alum. Flour undergoing fermentation produces dyspepsia, flatulence and diarrhœa. Ergoted wheaten flour is rare, but its consequences are serious, such as severe gastro-intestinal symptoms followed by fever and prostration. Acid flour makes acid and disagreeable bread. Ill-raised or imperfectly baked bread causes dyspepsia and diarrhœa. Nutritive power is diminished by the admixture of inferior grains; and also by the use of alum, which combines with phosphoric acid to form an insoluble phosphate. Alum in large amount is liable also to act astringently and produce constipation.

384. **Barley** is inferior to wheat in nutritive value, being comparatively deficient in nitrogenous constituents.* *Pearl barley*, the seeds completely freed from the husk, alone requires notice here. Boiled and eaten with milk it is a valuable food for invalids and children. The decoction is a nutritious drink. The barley should be free from insects and other dirt.

385. **Oatmeal**, weight for weight, contains more nutritive material than wheat flour, to which it is inferior only in starch, exceeding it in fat more especially. A pound of it affords 882 grains (2 oz.) of albuminate, 392 of fat, 4,088 (9·3 oz.) of starch &c., 378 of sugar and 210 of salts. It is readily cooked, either by boiling or by making into cakes; but, containing little or no gluten, it cannot be made into bread. It includes a good deal of indigestible cellulose and the husk is irritant unless finely ground, but it is capable of being used as the staple article of food for long periods. The decorticated grain is called *groats* and is used for making gruel; and the husks or "*seeds*" when steeped in water for a few days, until they become a little sour, yield a liquid which, boiled down to the consistence of gruel, is called *flummery* or *sowans*. The coarser oatmeal is, the more prolonged and careful should be its cooking. Adulteration with cheaper grains is common and requires microscopical examination for its detection.

386. Indian corn or **maize** is not much used in this country for human food, although it is a highly nutritious grain. Boiled in the cob, in water or milk, before ripeness it is excellent as a "vegetable." The ripe seeds are hard and covered with a silicious husk, and careful cooking is necessary to render the meal digestible. It should be steeped in water for two or three hours and then boiled slowly for four or five, making a kind of porridge. A pound of the meal contains 777 grains (1·8 oz.) of albuminates, 567 of a peculiar yellow fat, 4,529 (10·3 oz.) of starch &c., 28 of sugar and 119 of salts. It is said to be unfit for prolonged use as a staple food, producing disease and ultimately death. When the flour of this grain is treated with a weak alkaline solution, which modifies the

* A pound of barley meal contains 441 grains (1 oz.) of albuminate, 168 of fat, 4,858 (11·1 oz.) of starch, 343 of sugar and 140 of alts. The husk is very irritating to the intestines.

harshness of its flavor and removes all its gluten, it forms such preparations as Corn Flour, Oswego Flour, Maizena &c., valuable accessory foods, but unfit for exclusive use. These substances, though called flours, are only starches and by themselves incapable of supporting life.

387. There are four other cereals, whose seeds form the staple food of large numbers of the inhabitants of this country, and which belong to the class of **millets.** They are sometimes called *dry grains* from the mode of cultivation, without such artificial irrigation as rice requires. Those are *cumboo** or *bájra*, *cholam*† or *jawáree*, *rágee*‡ and *varagoo.*§ As a class they form a more nutritious dietary than rice, and their average composition may be taken as nine per cent. of nitrogenous aliment, 2·6 of fat, 74 of carbo-hydrates and 2·3 of salts. More accurately, their composition is given as follows :—

——	Penicillaria spicata.	Sorghum vulgare.	Panicum miliaceum.
Water	11·80	11·95	12·22
Albuminates	10·13	8·64	9·27
Dextrin	..	3·82	0·13
Sugar	..	1·46	1·80
Fat	4·62	3·90	7·43
Starch	71·75	70·23	59·04
Silica	..	..	0·11

388. In the following Table the **nutritive value** of these grains is shown by the quantity of each alimentary principle in one pound of the meal freed from outer husk :—

——	Cumboo.	Cholum.	Varagoo.
Albuminate.	709 grs. (1·6 oz.)	605 grs. (1·4 oz.)	649 grs. (1·5 oz.)
Fat ..	323 ,,	273 ,,	520 ,, (1·2 oz.)
Starch &c.	5,022 ,, (11·5 oz.)	5,183‖ ,, (11·8 oz.)	4,771 ,, (10·9 oz.)
Sugar ..	....	102 ,,	126 ,,
Salts ¶ ..	182 grs.	119 ,,	210 ,,

* Penicillaria spicata. † Sorghum or Panicum vulgare.
‡ Eleusine corocana. § Panicum miliaceum.
‖ Husks included.
¶ The ash of these seeds when freed from silica (of which there is a considerable quantity) consists of about 50 per cent. of phosphoric acid in combination with magnesium, potassium and a little sodium. It contains no lime.

389. The first three of these grains are prepared for food by removing the outer husk, grinding the remainder into meal and making with this either cakes or a kind of thick porridge. In the case of rágee more especially complete comminution and careful boiling are necessary to obviate indigestibility, leading to diarrhœa and insufficient nutrition. Varagoo is generally cooked in the same manner as rice; that is, boiled carefully and eaten whole.*

390. The last group of highly nitrogenized alimentary substances are the PULSES, the seeds of leguminous plants. These contain a large proportion of an albuminate called legumin or vegetable casein; which is coagulable like casein, so that cheese is prepared from it in China. Owing, however, to their comparative indigestibility by man they are inferior as food to the flesh of animals and are incapable of being digested in sufficient quantity to support human life by themselves. Added in small amount to starchy or fatty foods they are of great value; eaten, for instance, with rice in India or with fat pork or bacon in Europe and America. They keep well, although becoming harder by time and requiring more careful preparation. They are rich in sulphur, potassium and calcium, but inferior to the cereals in magnesium and phosphoric acid. They require slow and protracted boiling, and, if old, should be steeped for 24 hours and crushed before attempting to cook them for food. The water should be soft, as lime forms an insoluble and indigestible combination with legumin. Lastly, unless when the seeds are fresh, the husk should always be removed.

391. Many species of leguminosæ yield seeds which are used as food in India. They differ in flavor and in popularity, but little in nutritive value or digestibility. The following Table gives the composition in grains of one pound of the most ordinary pulses of the country :—

* The manufacture of rágee or cholum bread has never yet been tried, but from the known nutritive value of these grains, they would probably yield a very wholesome bread. The Italians make their very finest bread of the Panicum italicum, a millet.

	Batáni, (*Pisum sativum*).	Toor, (*Cajanus indicus*).	Masoor, (*Ervum lens*).	Kooltee, (*Dolichos*).	Chenna (*Cicer arietinum*).
Albuminates ..	1,957	1,553	1,760	1,629	1,583
Fat	103	136	118	154	263
Carbo-hydrates ..	4,155	3,106	4,189	4,157	4,122
Salts	174	218	134	223	182

392. The first of these is the ordinary garden pea. Toor and masoor, under the common name of dhál are the favorite pulses added by the natives to their meal of rice . the latter being also the basis of the "delicious Revalenta Arabica food." Khooltee is the usual food of horses in Southern India and is generally boiled, thus losing some of its nutrient properties. Chenna steeped merely in cold water is used for the same purpose in other parts of the country. The Kasáree dal (*Lathyrus sativus*) is a poor and innutritious pulse, which is said to produce paraplegia if allowed to form the principal article of food.

393. By combining an alimentary substance of this class with flesh and fat, concentrated foods of great value may be prepared. Of these, **erbswurst** has stood the test of actual employment in a campaign. It consists mainly of pease-flour with which meat and fat are intimately mixed, the whole being enclosed in a case like an ordinary sausage. The outer coat of the leguminous seeds is removed and the fascia and areolar tissue of the meat: both are then baked, ground and mixed with fat, salt and pepper. A highly nutritious and agreeable soup is readily prepared from this sausage; and one weighing a pound supplies a sufficient meal to three men. It contains 861 grains (1·9 oz.) of albuminates, 2,352 (5·4 oz.) of fat, 2,149 (4·9 oz.) of carbohydrates and 504 of salts. The process of manufacture is not published but imitations can readily be made.

394. Almost all the articles of food which have hitherto been mentioned contain fat in greater or less proportion. The quantity thus supplied, however, is insufficient for the wants of the system and the deficiency is made up by the use of animal or vegetable FATS. The former are more widely employed, and, (as has already been remarked), are more readily assimilated than the latter. *Butter* or *ghee* is the most extensively used of the animal fats ; *suet*, *drip-*

ping and *lard* will also require notice. Very many vegetable oils are used for food, differing in price and flavor but not at all in dietetic value. All these fatty substances are mainly composed of the solid fats stearine and palmitine and the liquid fat oleine, the liquidity of the particular substance depending upon the proportion of the last which it includes.

395. **Dripping** is the fat which is melted out from roasted or baked meat; and, retaining some of the aromatic principles of the latter, it is superior in flavor to **lard**—the "leaf-fat" of the pig—the two being equal in other respects. **Suet** is the visceral fat of beef and mutton, and in nutritive value closely corresponds to butter. Its hardness and its inferiority in flavor prevent its use in its natural condition, and it is best employed, cooked along with flour, in puddings &c. It should be chopped small for this purpose, to ensure thorough intermixture with the flour and to promote digestibility.

396. When milk or cream is briskly agitated for some time, the fat-globules become aggregated into little masses of **butter**. It contains (besides fat) milk, water, some casein; and salt is almost always added to it. It is a wholesome and easily digestible article of food. When boiled and strained, so as to remove the casein and nearly the whole of the water, it constitutes **ghee**, which has all the advantages of butter for culinary purposes and which, when pure, may be kept without rancidity for an unlimited time.

397. Butter, unless intended for immediate use, should be washed quite free from milk; a sour smell indicates that washing has not been complete. It should be homogeneous in color, streaks indicating admixture of foreign fat; salt should not exceed 8 per cent., 2·5 being the average proportion. It should contain not less than 80 per cent. of butter-fat and water should range from 5 to 18 per cent.

398. The presence of **casein** in butter and the putrefactive changes which it undergoes are the chief causes of rancidity; and this is productive of dyspepsia and other derangements in those who use the food. The less casein present, therefore, the better is the butter. If a sample be heated in a test-tube the melted butter in the upper portion

should occupy at least twice as much space as the unfused casein below. A more accurate estimation may be made by weighing the residue after the fat of the butter has been dissolved out by hot ether. The weight should not exceed 5 per cent. of that of the butter.

399. The commonest adulterants of butter are water and foreign fats. The **examination** of a sample is thus performed. About one grain is dried in a small platinum dish over a water-bath, for three hours, and thereafter at hourly intervals until the weight is constant. The loss of weight is *water*. The dry residue, dissolved in dry ether, and again evaporated to dryness, gives *fat*. The detection of foreign fats is made by determining the percentage of insoluble fatty acids obtainable from the sample, which should not fall below 88·5. The process is described in Messrs. Helmer and Angell's work, *Butter, its Analysis and Adulterations*.

400. Butter is **preserved** by the addition of salt, in proportion varying from four to eight per cent. On the small scale, sugar with a little salt is a good antiseptic and corns of black pepper are said to be useful aids. Water containing half an ounce of acetic or tartaric acid in a gallon will preserve butter in a closed vessel for a considerable time.

401. The CARBO-HYDRATES include the starches and the sugars. Under the former head it will be sufficient to notice the *potato* and such substances as *arrow-root*, *sago*, *corn-flour* &c. which consist almost entirely of starch. *Cane-sugar* and *palm-sugar* are the only members of the second group which require remark.

402. The **potato** contains a large proportion of starch and some valuable salts, besides small quantities of albuminates, of fat and of sugar. Water amounts to 75 per cent. Thus one pound of potatoes yields 1,316 grains (3 oz.) of starch, 214 of sugar, 147 of albuminate, 14 of fat and 49 of salts.* The addition of nitrogenous and fatty foods to a potato dietary is, therefore, necessary. Under ordinary circumstances the potato is chiefly valuable as an anti-scorbutic, that is to say, for its saline constituents; but it has a high nutrient value in other respects also, its starch being abundant and readily digestible. When no other vegetable is obtainable the allowance of potato should not fall below half a pound a day.

---

* Payen's analysis of the potato gives:—albuminates 2·50 per cent., starch 20·00, cellulose 1·04, sugar and gum 1·09, fat 0·11, salts 1·26, water 74·00.

403. The **salts** of the potato vary from 0·7 to 1·5 per cent. The most important are those which on incineration or by digestion form carbonates, as the tartrates, citrates and malates. Potassium is the base most abundantly present, others being magnesium, calcium and sodium. Phosphoric acid contributes about 10 per cent. of the ash.

404. In **choosing** potatoes, moderate size, firmness of structure and absence of appearance of disease on section should be attended to. After cooking they should be mealy, not damp or waxy, as they are likely to be if grown in damp soil. When kept long they become dry and shrivelled, losing not only water, but also much nutritious matter; they are also liable to germinate and so to deteriorate considerably in value. The specific gravity of a potato should not be less than 1,105.

405. Potatoes should be **cooked** thoroughly and slowly, ensuring the disintegration of the starch-granules without hardening and rendering indigestible the small quantity of albuminate present. When they are merely one of several accessory vegetable foods supplied in abundance, the manner of cooking matters little, provided these conditions are fulfilled: but, when a fixed ration only is supplied, it is desirable to prepare it so as to secure as much as possible of the salts. For this purpose boiling (or steaming) is better than roasting; a pound of potatoes losing about half an ounce in the former process and two to three ounces in the latter. The skin should not be removed, because from one-fourth to one-third of the weight is lost when potatoes are peeled before boiling, while after boiling the peel removed does not amount to one-sixteenth; the skin besides prevents a large proportion of the salts from passing into the water. The addition of common salt to the water diminishes the loss of salts due to boiling.

406. The great antiscorbutic value of the potato renders its **preservation** for use on voyages, marches &c. a matter of great hygienic importance. On the large scale the tubers are kept for many months in heaps protected from the atmosphere by straw and a thick layer of earth. For shorter periods they should be placed on dry sand, not in contact with each other, occasionally turned; and any showing signs of decay should be at once removed. Boiling for a few minutes renders potatoes less liable to rot. Peeled, sliced and stored in casks in layers alternating

with molasses, they will remain unchanged for an indefinite period. Sliced, carefully dried and reduced to powder, they retain most of their valuable properties. In Edward's patented process boiled potatoes are granulated by forcing them through a perforated plate and then dried.

407. The **other starchy foods** differ from the potato, in that they contain practically nothing but starch and water; of the latter 15 to 20 per cent. They are identical in chemical composition and in nutritive value; they differ in flavor, digestibility and price. They form emulsions with water, and when prepared with milk are useful foods for invalids and children. Without milk they are only partially digested, especially by the latter, and if fully digested are obviously incapable of maintaining health or life. Several starches are included under the name of *arrow-root;* the principal of which are the West Indian, or "Jamaica," obtained from the *Maranta arundinacea*, the "Portland" from the *Arum maculatum*," "Tous-les-mois" from the *Canna edulis*, "East Indian" from the *Curcuma angustifolia*, "Brazilian" from the *Manihot utilissima*, "Tahiti" from the *Tacca oceanica* and *pinnatifida*. All these should be white and should form a firm jelly immediately when hot water is poured on, this jelly remaining unchanged for three or four days. Such taste as they have should be agreeable. Under the microscope the granules of Maranta starch are ovoid, with distinctly marked concentric lines and a hilum at the larger end. The granules of Curcuma are large and oval, with distinct but imperfect concentric lines and an indistinct hilum at the smaller end. Both these arrow-roots, but especially the former, are liable to adulteration with other amylaceous substances, and most commonly with *potato-starch* which is cheap. This substance is called *farina* and makes a good jelly, which, however, turns thin and sour in twelve hours. Its granules are large and pyriform, with a hilum at the smaller end, and swell under the influence of weak liquor potassæ. *Tapioca* is obtained from the pith of the *Jatropha manihot*, dried and partially cooked on hot iron plates. It is steeped in cold water before preparation as food. The starch-grains are small, with concentric markings and a central hilum. *Sago* is prepared from the pith of the *Sagus lævis* and other palms. The granules are irregularly pyriform, with slightly marked lines and a stellate hilum at the smaller

end. *Corn-starch, corn-flour,** *Oswego flour* are the starch of maize, and their polygonal granules are easily recognizable under the microscope.

408. Two kinds of **sugar**, both sucroses, are in common use in India; one obtained from the juice of the *sugar-cane*, the other, called *jaggery*, from the sap of date, palmyra and other palms. The latter, owing to its imperfect preparation, is much inferior in sweetening and nutritive power and corresponds to unrefined cane-sugar rather than to the more or less crystallized substances usually employed. The *Acarus sacchari* will be found in most samples of unrefined sugar, if two or three drams be dissolved in a large glassful of tepid water and allowed to rest for an hour or two: the mites will be seen on the surface and on the side of the glass. The ash of raw sugar ranges from 0·49 to 0·61 per cent. Crystallized sugar should be nearly white, dry and entirely soluble in water. The last quality shows freedom from the ordinary adulterations, sand and flour; the admixture of the cheaper grape-sugar being highly improbable in this country. The white powdery sugar obtainable in most bazaars generally contains a considerable proportion of insoluble material. Sugar includes on the average about 5 per cent. of water; the uncrystallizable part of the juice, constituting **treacle** or *molasses*, containing about 23 per cent.

409. In dietetic value **honey** is equivalent to the grape-sugar of which, partly crystallizable partly not, it chiefly consists. Its flavor varies with the kind of flowers from which it is produced: *Narbonne* honey, for example, being derived from the flowers of rosemary and other labiatæ. It is occasionally poisonous, when obtained from certain poisonous plants, as azaleas. In Europe adulteration is common and the necessity for analysis is indicated if the sample yield an appreciable amount of ash, that of pure honey, being a mere trace.

410. The principal nutrient value of the foods classed under the head of "vegetables" lies in the SALTS which their juices contain. Besides this advantage they are valuable for imparting flavor and variety to an otherwise

* Some "corn-flours" are *rice* starch.

monotonous dietary. They should be considered an indispensable element of diet, the absence of which inevitably leads to a scorbutic condition of health and to increased liability to epidemic disease. The kind of fresh vegetables supplied is of little importance, the nutritive value of most of them being, except as regards salts, insignificant. *Parsnips* (which are, however, rare in this country) and *carrots* are somewhat superior to others. *Turnips* contain even a smaller amount of solid nutriment, their percentage of water being 91. *Onions* are superior to turnips in nutritive and antiscorbutic power, while their essential oil enables them to act also as a condiment. The *yam* and the *sweet-potato* are intermediate in power between vegetables and the potato, and may be used instead of the latter when not obtainable. It is to be remembered that when ordinary vegetables are scarce or cannot be had almost any fresh herb not actually poisonous should be added to the dietary, especially in the cases of prisoners and of soldiers in the field. Salt is sometimes added to the water in which vegetables are boiled, with a view to preserving their color. It makes them harder than they would otherwise be.

411. The following Table shows the nutritive value, in grains, of one pound of each of the vegetables mentioned above* :—

—	Cabbage.	Parsnips.	Carrots.	Turnips.	Jerusalem Artichoke.	Sweet Potato.	Yam.
Albuminates ..	16	77	91	84	63	105	140
Fat	35	35	14	..	63	21	35
Starch &c. ..	} 406	672	588	357	} 1,415	1,260	1,470
Sugar		406	427	147		56	14
Salts	42	70	70	42	113	203	91

412. Fresh vegetables are sometimes unprocurable, especially on the line of march or in newly occupied stations.

* *Mushrooms* contain a high proportion of albuminates—328 grs. in a pound, but it is difficult to distinguish edible from poisonous fungi. Their other constituents, in grains per pound are :—fat 28. starchy and saccharine matters 242, salts 32.

Under such circumstances advantage should be taken of the infinite variety of **fruits** which India supplies. At all times this resource should receive greater attention than it usually does and fresh or boiled fruits should be occasionally substituted for a vegetable ration. Very many common and cheap fruits contain citric, tartaric, oxalic, malic or other organic acid in combination with alkalies or alkaline earths and are powerfully antiscorbutic in properties. Many are grateful as well as useful in the raw state, others require the addition of sugar and boiling or stewing to make them palatable. Some (as the plantain, which contains about 27 per cent. of solid matter of equal nutritive value with rice) are useful as proper foods.* The freedom of the poorer classes of the native population of the country, under ordinary conditions, from scorbutic affections, may be attributed to their constant use of their acid and sub-acid fruits.

413. In the following Table the nutritive values of some fruits are given in grains per lb. :—

—	Apple.	Apricot.	Date.	Gooseberry.	Grape.	Peach.	Pear.	Plantain (Banana).	Plum (Greengage).	Raspberry (red).
Albuminates	15	58	..	31	58	32	18	337	33	38
Sugar	531	80	4,060	564	96	111	490		207	330
Free acid (as malic)	73	63		95	71	43	5	1,376	67	95
Pectous substances	272	75		88	101	91	323		734	157
Ash	33	62		32	33	32	23	55	25	54

414. Failing a sufficient supply of fresh vegetables or fruits, the necessary antiscorbutic element of food should be supplied artificially, either by preserved articles or by a ration of **lemon-juice** or lime-juice.† This contains free citric acid. a little combined malic and phosphoric acids and potassium ; the first being the essential constituent. The

† On the western coast of India plantains enter very largely into the dietary of the people. The green fruit is usually sliced and fried in ghee, and a little salt added, and in this condition the plantain occupies the place of the potato in European dietaries.

* The lime contains more citric acid than the lemon.

juice is prepared for the market either by boiling or by adding 10 per cent. of a strong spirit, brandy or whiskey, to it. When neither fresh nor dry vegetables can be procured, one ounce of the juice should be issued daily to each man, with half its weight of sugar to render it palatable. This quantity will generally contain from 25 to 30 grains of anhydrous citric acid, about 0·5 gr. of potash and 0·035 gr. of phosphoric acid.

415. The characters of **good juice** are;—freedom from turbidity and mucilaginous deposit; acidity of taste without bitterness; a peculiar, easily recognized, fragrance of the juice itself and of its extract prepared by careful evaporation; alkalinity of the ash; a specific gravity (after removal of spirit if present) not below 1,030; acidity of not less than 30 grains per fluid ounce, reckoned as anhydrous citric acid; and freedom from adulteration with tartaric, sulphuric or hydrochloric acid.

416. In the **examination** of the article with reference to these points the *specific gravity* is determined after evaporating to one-half and making up to original bulk with distilled water, so as to eliminate the effect of any alcohol which may have been added. The *acidity* is ascertained by means of the standard alkaline solution (441) each c. c. of which represents 0·0064 grm. of citric acid per litre, or 0·28 grain per ounce. It will be more convenient to dilute 10 c. c. of the juice to 100 c. c. with distilled water and to determine the acidity of 10 c. c. of the dilution, equivalent to 1 c. c. of the juice itself. *Tartaric* acid will be detected by the precipitation of the acid potassium tartrate in 24 hours after the addition of a little solution of potassium acetate to the suspected juice; *sulphuric* by dilute hydrochloric and barium chloride;* *hydrochloric* by dilute nitric and silver nitrate.

417. In the absence of vegetables, fruits and lemon-juice or lime-juice, the best substitute is citric acid, either alone or in combination with potassium or sodium.† Vinegar will be useful; so also may be alkaline tartrates, acetates,

* A solution of sugar, acidulated with sulphuric acid, has been sold as lime-juice.

† Artificial lime-juice may be prepared by dissolving 1¼ oz. of citric acid, 45 grs. of potassium carbonate and 2½ oz. of white sugar in a pint of cold water, flavoring with lime-peel or oil of lemon.

lactates &c. This contingency, however, will rarely require to be practically considered.

418. CONDIMENTS are accessory foods, used to stimulate appetite and digestion and to add flavor to insipid substances. Vegetables, as we have seen, fulfil these objects to a certain extent; but there are pungent products of the vegetable kingdom which are more specially employed for this purpose. Such are *peppers* and other spices, *mustard*, *vinegar* and sauces or other combinations of these. While the moderate use of these accessories is useful and, in cases where the staple food (as rice) is insipid, necessary, it is to be noted that they are liable to abuse by stimulating appetite already sufficiently strong and by accustoming the digestive system to irritants, so that its natural power deteriorates.

419. The term **pepper** is applied to several different substances. *Cayenne* or *red* pepper is the ground seed-vessel and seeds of various species of the solanaceous Capsicum. Before pulverizing they are called *chillies*. It is in this condition that they are usually purchased in this country; consequently adulteration, which is almost universally practised in Europe upon the ground pepper, is not to be apprehended here. The ash should not exceed 6 per cent. and the pepper should give up 25 per cent. of its weight to alcohol and 9 or 10 to ether. It differs from the other kinds of pepper in being pungent without being aromatic. *Black* and *white* peppers are the product of the *Piper nigrum*; the former consisting of the entire ripe fruits dried, the latter of the central part of the seeds only. Adulteration of ground pepper is exceedingly common in Europe, but may easily be obviated here by buying the seeds whole. The ash of black pepper should not exceed 5·5 per cent.

420. The same precaution is applicable to **mustard**, the seeds of two or more cruciferous plants of the genus *Sinapis*. The seeds are ground and the husks sifted from the flour, the residue yielding to expression a useful fixed oil. All commercial samples of ground mustard may be said to be adulterated, turmeric, linseed meal, pease flour, yellow ochre being common adulterants, while cayenne is added to restore pungency. The mustard grown in India is inferior in sharpness of flavor to that imported from Europe, and if purchased in powder in the bazaar is quite as little likely to be genuine as the foreign article.

421. **Curry powder** is composed of many substances, turmeric being the principal ingredient. Coriander seeds and black pepper are the ingredients next in importance, while small quantities of cayenne pepper, cardamoms, cumin and fenugreek are also indispensable. A little ginger, some cloves and allspice are sometimes added. The complexity of its composition affords a wide field, not only for variety of stimulating flavors, but also for ingenuity in adulteration, and the manufactured article as found in Europe is rarely genuine. In India the materials may be obtained whole and separately in any bazaar and adulteration can be altogether avoided.

422. Acetates are supposed to belong to the class of organic salts capable of conversion into carbonates in the system and, therefore, to be valuable as antiscorbutics. Hence **vinegar**, which is a dilution of acetic acid, is not a condiment merely, but also a saline food. In the former capacity it promotes the digestion of salt meat, fish and other foods, not only by stimulating salivary and other digestive secretions, but also by softening the tissue. Pickled vegetables or fruits form the most convenient medium for taking vinegar with the food, and their moderate use, especially when the supply of fresh vegetables is deficient, should be encouraged.

423. Vinegar is the product of the acetous fermentation of weak alcoholic liquors, that is, of the oxidation of their alcohol by the action of the suitable ferment. It is **obtained** commercially from wine or from malt liquor, or it may be prepared directly by exposing a solution of sugar to the air, when the alcoholic and acetous fermentations go on simultaneously or in immediate succession. Another form, "pryroligneous acid," is one of the products of the destructive distillation of wood. These various kinds of vinegar are of course, if of equal strength, of equal dietetic value. They differ in delicacy of flavor and in price. Wine vinegar is distinguished from alegar or malt vinegar by the darkening of the former when sodium carbonate is added and by its giving a purple precipitate on addition of ammonia.

424. The **strength** of vinegar should not fall below 3 per cent. of acetic acid, and good samples contain 5 per cent. Some samples of wine vinegar contain 8 per cent., an amount which should not be exceeded. It is ascer-

tained roughly by taking the specific gravity, which ought to be as high as 1,022 and should not be lower than 1,015. The quantity of acid present can be accurately estimated by means of a standard alkaline solution; or by observing how much pure dry sodium carbonate must be added to a known weight of the vinegar to neutralize its acid. This quantity multiplied by 0·962* gives the acidity, reckoned as acetic anhydride.†

425. The commonest **adulteration**, and one which to a certain extent is legalized, is the addition of sulphuric acid. One-thousandth part by weight of this substance may legally be added to British vinegar, but this quantity is not unfrequently exceeded, raising the specific gravity and increasing fraudulently the acidity of the vinegar. The extent of this adulteration is ascertained by adding a few drops of hydrochloric acid to a known weight of the sample, and then solution of barium chloride until all the sulphuric acid is precipitated as barium sulphate, which is collected, dried and weighed. The weight multiplied by 0·42‡ gives the quantity of sulphuric acid present. Allowance should be made for oil of vitriol legally added and for the probable presence of sulphates in the water with which the vinegar has been made. Tartaric acid is sometimes added as an adulterant: it (as well as sulphuric) remains behind on distillation, the acetic coming over. The only other adulterant requiring notice is *copper*, which is often added to the vinegar with which pickles are prepared, in order to improve their color. This is readily detected by the deposition of a red film of metallic copper on a bright needle or knife-blade held in the vinegar for a short time.

426. The last subject to be noticed in connexion with food is that of DRINKS. Omitting consideration of those which consist merely of water flavored with substances

* Each molecule of Na_2Co_3 (106) neutralizes a molecule of $C_4H_6O_3$ (102). 106 : 102 : : a (weight of carbonate used) : x (weight of anhydrous acetic acid. Therefore $x = a \times 0·962$.

† This method may be substituted for the use of the standard alkaline solution in other determinations of acetic acid.

‡ $BaSO_4$ (233) : H_2SO_4 (98) : : a (weight of sulphate) : x (weight of acid) $\therefore x = a \times 0·42$.

destitute of any special physiological action we may divide the remainder into two groups—the *alcoholic* and the *alkaloidal:* the former class being sub-divided into *spirits, wines* and *malt liquors;* the latter including *coffee, tea* and *cocoa.*

427. The most powerful action of the alcoholic group being due to the **ethyl alcohol** which its members contain, it is necessary to state as briefly as possible the effects which this substance produces upon the system generally and upon the different organs of the body. Small doses stimulate the *stomach*, promoting secretion of the peptic fluids and aiding digestion. In excess alcohol leads to fatty degeneration and ultimately to atrophy of the glands and consequently to impairment of digestion and of appetite. Habitual indulgence in excess of alcohol produces congestion and enlargement of the *liver* and finally contraction of the capsule; or the latter effect may occur without preliminary deposit. The *kidneys* become contracted and atrophied after continued excess of alcohol. Under its influence the carbonic acid exhaled from the *lungs* is diminished, while habitual intemperance favors chronic bronchitis and lobular emphysema. It increases the force and frequency of the *heart's* action when first ingested, subsequently lowering both; while chronic indulgence tends to produce fatty degeneration. On the *nervous system* it generally acts as a depressant, diminishing activity of thought, control of the will over mental action and acuteness of special sense. Muscular power and co-ordination of muscular movements are also impaired, poisonous doses sometimes destroying life by paralysing the respiratory muscles. The *metamorphosis of tissue* is rendered less active by the ingestion of alcohol, as shown by diminished excretion of urea and carbonic acid. While this effect is beneficial in moderation, economizing tissue and delaying change, in excess it leads to accumulation of imperfectly oxidized products, such as oxalic and uric acids. In general there can be no doubt of the evil effect of alcohol in excess upon health and longevity, while complete abstinence from the use of it as an article of daily consumption is, under ordinary circumstances, compatible with perfect health and length of life. Tubercle in brain, liver, kidneys, spleen, bowels, mesenteric glands, peritoneum &c. is twice as common in persons

taking alcohol to excess as in others. Alcoholics are more liable to fatty degeneration and to insanity; are more obnoxious to diseases generally, and shorter-lived. On the other hand it can scarcely be doubted that the moderate use of alcohol, especially in its more dilute conditions as wine and malt liquor, is attended with no injury to mind or body; is, in fact, as innocuous as it is nearly universal. It will be seen presently that wine and ale &c. have valuable hygienic properties independently of the alcohol which they contain. Moderation will necessarily have different meanings in different cases, and it is impossible to lay down a fixed rule suitable to every one and to all conditions. The nearest approach to such a canon that can be made in the present state of our knowledge is, that an adult man, in health and ordinary work, should not take in 24 hours, in any form of alcoholic drink, more than $1\frac{1}{2}$ oz. by weight of absolute alcohol; while $\frac{3}{4}$ oz. will be a safe limit for a woman under the ordinary conditions of European life in this country. To this it may be added that it is better to take the limited quantity in the more diluted forms than as spirits, and that intemperance in the use of spirits is more injurious than excessive indulgence in wine or beer.

428. Of the value of alcohol in the treatment of disease it would be out of place to speak. Of its power in aiding resistance to disease little need be said, **malaria** being the only morbific influence against which the use of spirits is supposed to be prophylactic. It is not possible to speak positively on this point, evidence and opinion being conflicting. The almost universal use of alcohol in its strongest forms by tribes inhabiting malarious parts of the country appears to indicate an instinctive feeling of its necessity or value. The preponderance of medical opinion seems also to be in favor of the belief in its efficacy as a preventive of paludal fevers.

429. The alcohol with which we are concerned is the product of the alcoholic or vinous fermentation of sugar. Cane-sugar or sucrose, not directly fermentable, is first converted into grape-sugar, and this into ethyl alcohol and carbonic acid, with some other, secondary, products, as glycerine. When the alcohol amounts to about 25 per cent. of the fermenting solution of sugar, the process is spontaneously arrested, and distillation is necessary in

order to obtain a dilution containing a higher percentage. The various products of such fermentation and distillation are called **spirits.** They differ in strength, but still more in flavor; which depends either upon certain ethers developed during the manufacture or upon substances purposely added to them. Of such spirits there is a very great variety used in different parts of the world. It will be sufficient for our purpose to notice six only, namely, *arrack*, *brandy*, *whiskey*, *rum*, *gin* and *mhowa spirit.*

430. There are three kinds of **arrack**, two of which, *common* or *country* or *patté*, and *colombo* are consumed in large quantities in Southern India. The third, *batavia*, which is prepared from malted rice, is little, if at all, known in the Peninsula. Country arrack is distilled from a fermented solution of jaggery, the coarse sugar obtained from the juice of the date, cocoanut, palmyrah and other palms. In its preparation the bark of the *Acacia leucophlœa* is added to the hot sugar-solution, precipitating albuminous matters which would otherwise putrefy and communicate a nauseous flavor; and also increasing (by one-sixth) the quantity of alcohol produced. In an ordinary sample of this spirit, the percentage of alcohol by volume was found to be 45; 2·6 oz. would contain one ounce weight of absolute alcohol. In the preparation of colombo arrack the palm-juice itself, not a solution of the sugar manufactured from it, is fermented and distilled. This spirit, the best kinds of which are made from the juice of the cocoanut palm, is much superior in flavor to the other and bears a higher price. Its average percentage of alcohol is 42. About 2·4 fluid ounces would contain one ounce of absolute alcohol *by weight.*

431. Pure **brandy** is distilled from wine and contains from 50 to 60 per cent. of alcohol by volume. Its peculiar flavor is derived from certain ethers, œnanthic, acetic, butyric and valerianic. It should be quite free from sugar; its acidity should not exceed one grain per ounce, reckoned as tartaric acid (441); its solid residue (caramel added to color it, with matters taken up from the cask &c.) will be about 1·2 per cent., and its ash 0·05 to 0·2. The specific gravity ranges from 929 to 934. 2·7 ounces contain one ounce of alcohol. *British brandy* is corn spirit, often containing a considerable proportion of potato spirit, (amylic alcohol or fusel-oil) and flavored with ethers &c. to imitate the genuine spirit.

432. **Whiskey** is distilled from fermented infusion of malt, barley being in most cases the grain from which the latter is prepared, but oats and rye being also sometimes used for the purpose. The specific gravity is 915 to 920; the percentage of alcohol about the same as in brandy. It should contain no sugar, not more than 0·6 per cent. of solid residue and only a trace of ash. Acid (reckoned as tartaric) should not exceed 0·2 gr. per oz. 2·7 fluid ounces may be taken as the equivalent of the ounce of alcohol.

433. **Rum** is the strongest of the spirits in common use; its alcohol ranging from 60 to 77 per cent. and its specific gravity from 926 to 874. About 2·5 oz. contain one ounce of absolute alcohol. It may contain 0·5 gr. per oz. of acid, 1 per cent. of solid and 0·1 of ash, these last proportions being rarely reached by the pure rums manufactured in this Presidency. It is distilled from fermented molasses, the uncrystallizable part of cane-sugar, and owes its peculiar flavor and odor to butyric ether.

434. Geneva or **gin** is a malt-spirit flavored with the essential oil of juniper (to which it owes its stimulant action on the kidneys) and certain aromatics and spices.* *Hollands* is made of rye-spirit. The specific gravity is stated as 930 to 944; its alcohol at 49 to 60. About three ounces contain one of absolute alcohol. It may have about 2 per cent. of residue (of which one-half is sugar), 0·1 ash and 0·2 acidity.

435. In the Central Provinces and northward **mhowa** spirit is largely used by the Ghonds and others. It is distilled from the fermented juice expressed from the fleshy petals of the *Bassia latifolia*. The liquor retains the unpleasant mouse-like odor of the flower. The tree grows freely in Southern India, but the spirit is not manufactured or drunk.

436. In the **examination** of spirits the points to be inquired into (besides the fragrance, the flavor and other physical characters) are (1) the strength, (2) the acidity, (3) the solid residue, (4) the ash, (5) the presence or absence of sugar, and (6) adulteration, if suspected.

---

* Hollands and other pure gins contain nothing but spirit flavored with juniper-berries.

437. The **strength** of a dilution of alcohol is expressed in degrees O.P. or U.P. *i.e.*, over or under "proof;" or in percentage of alcohol, either by weight or by volume. British proof spirit contains 49·24 per cent. *by weight* of absolute alcohol: the percentage by volume varies with the temperature, being 57 at 60° F.* Its specific gravity at 60° F. is 0·920, (accurately 0·91984). A spirit 30° O.P. (for example) is one of which 100 measures, diluted with pure water to the strength of proof-spirit, would yield 130 measures: and a spirit 30° U.P. is one of which 100 measures contain 70 of proof-spirit. The strength of a spirit, over or under proof, is ascertained by means of Sikes' Hydrometer with its calculated tables. In ordinary cases, where the sample contains an inconsiderable amount of solid impurity, the hydrometer is applied directly. In other cases, where solid matters have been added, 12 measured ounces of the sample should be distilled until 10 or 11 ounces have come over, and the hydrometer used with the distillate made up to the original volume.

438. Percentage of absolute alcohol **by weight** being independent of temperature is more definite and accurate and is, therefore, generally employed for expressing scientifically the strength of spirits. The following Table gives some percentages by weight corresponding to proof-strengths ascertained by the hydrometer. For commercial purposes percentage **by volume** is used in expressing strength, but proportion by measure varies with temperature and the figures given in the third column of the Table are accurate only at the temperature of 60° F., (15°·5 C).

439. TABLE *of percentages by weight and by volume* (at 60° F.) *of absolute alcohol, corresponding to proof-strengths.*

Proof-strength.	Alcohol per cent. by weight.	Alcohol per cent. by volume (at 60° F.)	Proof-strength.	Alcohol per cent. by weight.	Alcohol per cent. by volume (at 60° F.)
O.P.			O.P.		
10·0	54·89	62·74	4·2	51·57	59·43
8·6	54·09	61·94	2·7	50·73	58·58
7·1	53·23	61·09	1·3	49·94	57·78
5·6	52·38	60·24			

* In the United States "proof-spirit" contains 50 per cent. of alcohol *by volume* at 60° F. or 43 *by weight*.

Table of percentages by weight, &c.—(Continued).

Proof-strength.	Alcohol per cent. by weight.	Alcohol per cent. by volume (at 60° F.)	Proof-strength.	Alcohol per cent. by weight.	Alcohol per cent. by volume (at 60° F.)
U.P.			U.P.		
0·3	49·04	56·86	26·7	34·98	41·82
1·9	48·17	55·96	28·8	33·92	40·63
3·4	47·33	55·10	31·0	32·82	39·40
5·0	46·46	54·19	33·2	31·68	38·10
6·7	45·53	53·22	35·6	30·50	36·76
8·3	44·65	52·30	38·1	29·24	35·32
10·0	43·76	51·36	40·6	28·01	33·90
11·7	42·84	50·39	43·3	26·73	32·41
13·5	41·86	49·34	46·1	25·32	30·77
15·3	40·90	48·31	49·1	23·88	29·08
17·1	39·96	47·29	52·2	22·38	27·31
18·9	39·04	46·29	55·5	20·77	25·39
20·8	38·04	45·20	59·0	19·11	23·41
22·7	37·03	44·09	62·5	17·42	21·39
24·7	36·01	42·96	66·0	15·78	19·41

440. The **acidity** of spirits is estimated as grains of tartaric acid per ounce. A standard alkaline solution is prepared, one cubic centimeter of which neutralizes 0·0075 grm. of tartaric acid. The number of c. c., therefore, required to render neutral one ounce of the spirit, multiplied by 0·1157,* is the acidity sought.

441. The **alkaline solution** is a solution of potassium hydrate of such strength, that 1 c. c. mixed with an equal quantity of a solution of 6·300 grms of pure crystallized oxalic acid in a litre of distilled water gives a neutral liquid. Each c. c. of this alkaline solution represents 0·0063 grm. of *oxalic*, 0·0051 grm. of *acetic anhydride*,† 0·0064 of *citric*,‡ or 0·0075 of *tartaric*§ acid.

442. The **solid residue** is found by evaporating to dryness on a sand-bath the remainder of the 12 ounces

* 0·0075 multiplied by 15·43, to bring grams to grains.

† 126 ($H_2,C_2O_4,2H_2O$) : 102 ($C_4H_6O_3$, *acetic anhydride*) : : 0·0063 : 0·0051.

‡ 126 : 192 ($H_3,C_6H_5O_7$) : : 0·0063 : 0·0096, but citic acid being tribasic and oxalic dibasic, two molecules of the former have the same saturating power as three of the latter, and two-thirds of 0·0096 are 0·0064.

§ 126 : 150 ($H_2,C_4H_4O_6$) : : 0·0063 : 0·0075.

from which the alcohol has been removed by distillation. A measured ounce of the spirit is weighed in the specific gravity bottle. This weight multiplied by 0·12 and divided into weight of dry residue gives the percentage of the latter in the spirit. The percentage of **ash** is similarly determined. **Sugar** is rarely present except in gin. Its amount is ascertained as before described (312).

443. The **adulterations** to which spirits are liable are very numerous. The addition of *water* will be detected by ascertaining deficiency in the strength; or by finding sulphuric acid (from the sulphates of the added water) in the sample, the absence of the free acid (itself sometimes fraudulently added) having been ascertained. Other substances, as *capsicum* or *cocculus indicus*, will be best detected in the extract, prepared by evaporating a few ounces of the spirit in a water-bath. The pungent taste of these adulterants will be readily recognized, and extract containing the latter will be fatal, with the characteristic symptoms of poisoning by picrotoxine, to small fishes placed in water to which it has been added. The common spirits of the country are supposed sometimes to be made more exciting by the addition of *opium*, *dhatura* or *cannabis*. The presence of the first will be detected in the extract (previously, if necessary, bleached by re-solution and filtration through animal charcoal) by adding a drop of ferric chloride, which will give a red color if opium is present. Extract containing dhatura will produce dilatation of the pupil if put into a cat's eye. Cannabis may be detected by administering the extract to some small animal and comparing the effects with the symptoms of intoxication with bhang &c.

444. A most pernicious impurity often present in spirits is **fusel-oil**, a name given to certain accidental products of alcoholic fermentation which distil over at higher temperatures than ethyl alcohol. The chief of these is amylic alcohol, or potato-spirit, of which potato-fusel-oil almost wholly consists. Raw grain produces more of this spirit than malt and potatoes yield much more than grain. Its effects on the system are very much more powerful than those of ordinary alcohol and much more deleterious. Its presence may be detected by evaporating a small quantity of the spirit from the palm of the hand or from a warmed dish. Its odor is characteristic, disagreeable and irritating;

sometimes exciting cough. It may be separated from the spirit by shaking the latter with an equal volume of ether and adding the same quantity of water. The ethereal liquid evaporated, first at the ordinary temperature and then by the application of gentle heat (to remove the ethyl alcohol) leaves the fusel-oil.

445. WINES contain, besides alcohol and water, certain ethers, free acid, sugar (not universally), mineral substances or salts, and a great variety of other matters grouped together as "neutral organic bodies," including gum, wax, resin, fat, glycerine, pectin, pectose, albumen and various coloring matters. The dietetic value of wine is very great, independently of the stimulant effect of its spirit, and excessive indulgence in it is not attended with so much mischief as the abuse of spirits. The quality of a sample of wine mainly depends upon the relation of its alcohol to its acid. Wine possesses powerful antiscorbutic properties.

446. Wines may be conveniently **classified** by taking as a basis the relations both of the alcohol and of the sugar to the acidity. Thus we shall have (1) the Strong Wines in which the average is 38 weights of alcohol and 7 of sugar to one of acid; (2) the Sweet Wines, in which the numbers are 15 and 30 respectively; and (3) the Light Wines, with alcohol ranging from 10 to 25 times the acid, and averaging 17·25, and sugar from 0 to 0·8, the average being 0·33.

447. The **strong** wines include port, sherry and madeira. They contain little acidity, the acid potassium tartrate being insoluble in alcohol; and spirit, which includes no acidity, being largely added to the genuine wine which forms their basis. In *ports* the average ratio of alcohol to acid very much exceeds the limit of 25. Of *sherries* the same may be said, but the excess is not so great as in ports; so that dry sherry, that is, sherry containing a disproportionately small amount of sugar, is drinkable, whereas ports similarly composed would be intolerable. The following Table (taken from Mr. Griffin's work) shows the composition, from the point of view at present adopted, of the strong wines from which the numbers given above are obtained :—

No.	Strong Wines.	Alcohol to 1 Acid.	Sugar to 1 Acid.
1	Old-bottled port	56·74	9·26
2	Newly-bottled port	45·87	12·58
3	Public-house do.	56·20	14·29
4	Madeira	28·55	6·76
5	Montilla, 1854	38·29	1·39
6	Do. newly bottled	40·43	1·52
7	Oloroso, 1843	37·27	1·58
8	Do. newly bottled	39·86	1·58
9	Oxford sherry	43·65	5·13
10	Public-house sherry	33·92	5·83
11	Tarragona	33·08	5·13
12	British port	23·47	11·70
13	British sherry	31·78	11·49
14	Como	22·47	5·95
	Average of all	37·97	6·73
	Do. of first 11	41·26	5·91
	Do. of 5 to 8	38·96	1·52
	Do. of 1 to 3	52·94	12·04

448. The **sweet** wines are very various in composition, as will be seen from the subjoined table. The sugar ranges from 1·5 to 3·5 times the acid; the alcohol from 20 to 40 times.

Sweet Wines.	Alcohol to 1 Acid.	Sugar to 1 Acid.
Lachryma Christi	17·05	33·22
Visanto	10·76	36·97
Cyprus	15·96	23·64
St. Georger	12·69	28·91
Champagne	15·34	20·51
Average	14·36	28·65

449. A first-class **light** wine will contain 450 grains of acid, reckoned as tartaric, in a gallon, 21 to 25 times as much alcohol as acid and no sugar; medium wines will have 15 to 17 parts of alcohol; and the common acid wines 9 or 10. A light wine will be of first-rate quality when its alcohol is 25 times its acid by weight; very good if 20; middling if 15; common if 10; sour if less than 10.

If the alcohol exceeds 25, the wine has had spirit added to it. The following Table illustrates these points:—

Light Wines.	Alcohol to 1 Acid.	Sugar to 1 Acid.
Santorin	14·90	0·61
St. Elie	16·43	0·37
Thera	25·40	0·36
Red Keffesia	16·26	0·00
White do.	21·73	0·53
Red Mont Hymet	14·99	0·00
Do.	19·17	0·00
White Mont Hymet	21·35	0·00
White Capri	16·03	0·74
Ofner	16·04	0·46
Erlaure	17·20	0·00
Szamarodni	15·56	0·47
Dioszeger Bakator	19·72	0·73
White Diasi	21·36	0·79
Red Voeslauer	18·98	0·53
Fronsac	14·95	0·52
Vin Ordinaire	9·71	0·16
Paysan's Bordeaux	15·01	0·19
St. Julien, 1858	15·24	0·38
Castle I. Hock	10·50	0·00
Rudesheimer	21·05	0·27
Average	17·22	0·34
Strongest	25·40	0·79
Weakest	9·71	0·00

450. It follows from what has been said that in the **examination** of wine, the *alcohol*, the *acid* and the *sugar* are the points of primary importance. If the analysis is carried further, the amounts of *solid residue*, of *ash*, of *volatile acid*, of *potash* and of *neutral organic bodies* will be determined. There is no means of accurately estimating the *tannin*, and *bouquet* can be judged of only by the educated palate and nose. The *specific gravity* of a wine conveys so little information that its determination is unnecessary.

451. With regard to the **alcohol** which wines contain they are described as "natural" when no spirit has been added to them, or "fortified" when their strength has been artificially increased. Natural wines contain from 6 to 12 per cent. of alcohol by weight, fortified, from 12 to 22. A wine of less than 6 per cent. strength is not drinkable.

For the estimation of alcohol the same apparatus is required as in the case of spirits, but greater care and accuracy of manipulation are necessary. Twelve fluid ounces of the sample are introduced into a non-tubulated retort, by means of a long funnel, so that none of the wine touches the tube of the retort. A few drops of caustic soda are next put in, in the same manner, in order to neutralize all the free acid, thus changing completely the color of the wine. Eight fluid ounces of distilled water are then introduced and the funnel carefully withdrawn without soiling the retort. Finally, about two grains of tannin are put in, by means of a long-handled spoon, without touching the interior of the retort, and the latter closely fitted to the condenser.* Distil at a gentle heat until at least ten ounces have come over. Make up the distillate to 12 fluid ounces with distilled water and ascertain the U. P. strength by Sikes' Hydrometer. The following Table gives the corresponding percentage of alcohol by weight and by volume at 60° F.

U. P. strength.	Alcohol per cent. by weight.	Alcohol per cent. by volume (at 60° F).	U. P. strength.	Alcohol per cent. by weight.	Alcohol per cent. by volume (at 60°F).
52·2	22·38	27·31	72·8	12·56	15·51
55·5	20·77	25·39	76·1	10·97	13·58
59·0	19·11	23·41	79·2	9·56	11·85
62·5	17·42	21·39	82·3	8·08	10·04
66·0	15·78	19·41	85·2	6·65	8·28
69·4	14·16	17·46	88·0	5·48	6·83

452. In the following Table the quantities by *measure* of some ordinary wines, which contain one ounce by *weight* of absolute alcohol, are given :—

* The water is introduced to ensure the whole of the alcohol being distilled off without burning the residue; the soda to prevent free volatile acids from coming over; the tannin to prevent the formation of glutinous bubbles which might splash liquid from retort to receiver.

Wines.	Ounces containing 1 oz. a. a.	Wines.	Ounces containing 1. oz. a. a.
Bucellas	7·3	Moselle	15·2
Burgundy	15·2	Nezmely (White Hungarian) ..	19·0
Champagne	12·6	Port	6·9
Claret	16·3	Do. South African.	6·8
Frontignac	9·0	Roussillon	6·4
Hock	13·4	Sauterne	19·0
Madeira, Cape ..	6·8	Sherry	6·6
Do. East India.	7·6	Vöslau (Red Hungarian)	14·1
Marsala	7·5		

453. The **total acidity** is best reckoned as grains of tartaric acid per gallon. Add to one carefully measured ounce of the sample standard alkaline solution until the acid is completely neutralized. The number of c. c. necessary multiplied by 185·16* gives the total acidity of a gallon. A good wine will contain from 300 to 450 grains; one with less than 300 tastes flat; one with more than 500 tastes sour. These rules are specially applicable to the light wines: in the strong wines deficiency of acid is masked by excess of alcohol, of sugar or of both, and they are thus drinkable even when their acidity does not exceed 250. Port averages 320 to 400 grains per gallon, and sometimes contains as much as 640; Sherry has 240 to 360 grains. In good Champagne, a sweet wine, the acid ranges from 320 to 480; but some samples of excellent wine have been found to contain 760. The light wines are, as a class, more acid than the others. Thus good Claret will have from 320 to 640 grains; in inferior samples the acid may run up to 960. The acidity of the Rhine wines ranges from 560 to 960.

454. Pure natural wines, if more than a few years old, rarely contain as much **sugar** as 1 per cent. In newer wines the per-centage ranges from 2 to 6. Fortified wines, in which the added spirit has arrested fermentation often contain 5 per cent. of sugar. The sugar which exists in unadulterated wine is invariably glucose or grape-sugar,

* That is, 0·0075 (440) multiplied by 15·43 to reduce to grains per ounce and by 160 to bring to grains per gallon.

and sucrose can only be present when it has been recently added. The slow action of the acids of the wine converts cane-sugar into grape-sugar; and, if there be reason to presume that the former is present, the process is imitated by boiling the sample gently for two hours with one-fifth of its volume of sulphuric acid diluted to one in six. When this has been done and the wine has cooled, the latter is rendered alkaline with sodium carbonate and the sugar-test applied in the following manner. The three steps of the process are *dilution*, *decolorization* and *estimation*. The preparation of the two test-solutions has been already described (313).

455. The object of **dilution** is to reduce the amount of sugar to about 0·6 gr. per ounce, the test not giving accurate results if the solution be strong in sugar. The quantity of distilled water to be added, therefore, depends chiefly on the sweetness of the wine, though also, in some degree, on its color and other qualities. The sweet wines, (as Tokay, Champagne &c.), may be tested with 40 minims, carefully measured, diluted to 4,000. For Port, Sherry, Madeira, Como and other strongly colored wines one fluid dram and a half may be diluted to four ounces. For the light wines, containing very little sugar, one ounce may be diluted to two; unless the color is strong, when the dilution must be greater.

456. For **decolorization** (A) *milk of lime*, (B) solution of pure *alum*, one part in twenty, (C) solution of *lead subacetate** and (D) solution of pure *sodium carbonate* are, or may be, required. Many light-colored wines need only to be rendered alkaline with (D), alkalinity being in all cases necessary to the application of the copper-test. All four substances are often needed with red wines. Put the suitable quantity of wine into a graduated glass vessel, add half the dilution-water (455) then sufficient milk of lime to make the wine alkaline, shaking well. Next add the lead solution, about one-tenth of the volume of wine which had been measured; shake and add the alum solution, about one-third of (C). Put in a little more water, shake

* Prepared by boiling together in a flask four parts of lead acetate and three of litharge (free from copper) with distilled water for half an hour, continually shaking and restoring water lost by evaporation. Filter and dilute to four volumes.

thoroughly, make up with water to the volume prescribed for each kind of wine, shake again and allow precipitate to subside. Filter upper portion when tolerably clear into a beaked glass, through a dry paper filter, and pour into a graduated burette.

457. For **estimation** put 10 c. c. of the copper-solution (or 5 of each if there are two separate solutions) into a porcelain dish with about twice the volume of distilled water and boil, by means of a spirit-lamp, for a few minutes. No red precipitate should appear: if a small quantity is formed, it may be removed by adding a few drops of caustic soda : if much, or if the soda fails to remove it, the solution is spoiled and should be rejected. After boiling thus for a few minutes reduce the heat until the solution merely simmers. Drop in the diluted and decolorized wine from the burette, stirring with a glass rod, until the mixture becomes colorless and a red precipitate settles at the bottom of the dish 10 c. c. of the copper-solution are thus decolorized by 0·05 grm. or 0·7715 gr. of grape-sugar. The weight of sugar in the volume of wine tested is, therefore, $\frac{b}{a} \times 0{\cdot}7715$ grains; b being that volume and a the quantity run from the burette into the test-solution. From this the weight of sugar per fluid ounce or per gallon can easily be calculated.

458. We have seen that many of the *strong* wines contain a large **quantity** of sugar. Sherry is sometimes almost quite free from it, but the average is 1,280 grains per gallon; Amontillado and Manzanilla having least. In Madeira the sugar ranges from 960 to 10,560 grains; in Marsala it is less. Port contains from 2,560 to more than twice as much; and the best qualities appear to be the sweetest. *Champagne* averages 3,840 grains, the range being from 960 to 4,480. The *light* wines—Clarets, Burgundies, Moselles and Rhine wines—contain little or no sugar.

459. It is unnecessary to add to what has been already said as to the manner of determining the **solid residue** and the **ash** (442). The former, in pure natural wines varies from 1,000 to 2,000 grains per gallon: in fortified wines and champagnes it amounts to 4,000, 5,600, even 7,000, chiefly sugar. The latter, consisting of potassium, sodium,

calcium, magnesium, manganese and iron in combination with chlorine, phosphoric and sulphuric acids, amounts to from 70 to 200 grains per gallon.

460. An attempt is sometimes made* to estimate separately the **volatile acids** which a wine contains; but for ordinary purposes it is quite sufficiently accurate to reckon the total acidity as tartaric. The estimation is conducted by distilling slowly four ounces of the wine with four ounces of water, (to which tannin is added if it be a sweet wine, but no soda in any case), collecting separately the first two ounces, the next ounce and as much more liquid as can be got over without risk of breaking the retort. The last instalment is found to be more acid than the first. The volatile acidity is chiefly due to acetic acid and may be estimated as acetic by the standard alkaline solution. The quantity of the volatile acids in a wine, on which probably its flavor depends to a considerable extent, is much more variable than that of the fixed acids; the latter being insoluble in alcohol beyond a fixed point, while the former (as acetic) may coexist in any degree with alcohol.

461. The **potash** in the incinerated residue is sometimes estimated by means of standard solution, but the process need not be described. The **neutral organic bodies** are determined by subtracting from the solid residue the sugar (457), the fixed free acid (453), the ash (459) and the acid assumed, when a complete analysis is made, to be in combination with alkalies and alkaline earths. Lastly, the **bouquet** depends on the formation of a great variety of ethers, acetic, pelargonic, tartaric, malic and others, by the interaction of alcohol and the corresponding acids. As wine grows older, more of these compounds are developed and the flavor and odor of the wine improve. It is impossible to estimate them chemically; they are appreciated only by the educated senses of taste and smell.

462. When wine is **faulty** without being spoiled completely, certain palliative measures may be adopted. Excessive *sourness* may be corrected by adding potassium tartrate, which forms the acid tartrate, replacing free tartaric. Milk is said to correct the same fault. Alkaline carbonates will neutralize excess of acid, but injure the bouquet, probably by destroying volatile acids. *Stringiness*, or the formation of mucilaginous substances in the wine, is removed by adding a decoction of tea; one ounce boiled in two quarts of water being used for 40 gallons of wine. *Bitterness* is corrected by hard water, or by sulphur. Charcoal removes the offensive odor of *putrescent* wine; and excess of tannin, causing *astringency*, is precipitated by gelatin.

---

* Of the free acid in *white* natural wines not more than one-fourth is volatile. In *red* wines the proportion is higher, but should not exceed one-third.

463. The important **adulterations** of wine are *water* and *alcohol*, both detected, (the normal strength of the wine being known) by determining the per-centage of alcohol (451). *Lime* salts are sometimes present in excess, owing to the custom in some vineyards of adding to sour wine a mixture of calcium sulphate, carbonate, chloride and oxide. The calcium acetate is formed. If the sample be evaporated to one-tenth of its volume and twice as much strong alcohol added, the acetate is dissolved and may be precipitated by ammonium oxalate; the sulphate and tartrate, naturally present, remain undissolved.

464. In the following Table* are given the principal **constituents** of 40 wines, in grains per gallon, with the exception of alcohol which is given in weight per cent. :—

Wines.	Alcohol, per cent.	Acid.	Sugar.	Solids.	Ash.	KHO.
Spanish and Portuguese.						
Madeira	16·25	400	2,703	3,470	365	78
Port, newly-bottled ..	17·30	265	3,333	4,750	250	95
Do. old-bottled ..	20·29	250	2,315	4,056	179	35
Do. public-house ..	20·08	250	3,572	3,600	300	84
Sherry, Montilla, 1854.	16·62	300	417	1,720	320	29
Do. newly-bottled.	17·56	300	455	1,745	325	29
Sherry, Oloroso, 1843.	15·09	280	442	1,740	320	29
Do. newly-bottled.	16·14	280	442	1,740	320	29
Sherry, Oxford ..	20·39	325	1,667	3,443	350	43
Do. public-house ..	17·50	360	2,100	3,200	..	18
Tarragona	15·42	325	1,667	3,110	320	76
British.						
Port	14·73	450	5,263	5,643	471	126
Sherry	13·56	300	3,448	3,825	320	86
Greek.						
Como	12·63	400	2,381	5,916	370	92
Cyprus	10·09	470	11,111	12,180	328	76
Lacryma Christi ..	9·70	430	14,286	17,856	362	76
Keffesia, Red	8·65	370	..	1,660	160	38
Do. White ..	11·91	380	200	1,510	129	50

* Abridged from Mr. Griffin's work.

Wines.	Alcohol, per cent.	Acid.	Sugar.	Solids.	Ash.	KHO
Greek—(Cont).						
Mont Hymet, Red	10·62	495	..	2,320	180	65
Do. do.	10·19	370	..	1,860	180	32
Do. White ..	9·84	320	..	1,434	134	36
Santorin ..	9·49	445	270	2,308	274	63
St. Elie ..	10·73	455	167	1,622	208	62
Thera	12·80	350	125	1,460	120	56
Visanto ..	6·44	460	17,007	18,300	410	85
Italian.						
Capri, White	10·40	450	333	1,360	200	73
Hungarian.						
Diasi, White	15·09	490	385	2,060	176	25
Dioszeger Bakator ..	12·07	425	311	1,316	126	46
Erlaure	8·91	360	..	1,714	134	45
Ofner	8·65	375	172	2,300	200	67
St. Georger	7·75	460	13,300	15,500	230	49
Szamorodny	9·64	430	200	1,340	100	45
Austrian.						
Voeslauer, Red ..	10·25	375	200	1,360	220	95
French.						
Bordeaux, Paysan's..	7.32	340	63	1,420	200	62
Champagne	7·95	375	7,692	8,980	180	34
Fronsac	10·74	500	260	1,640	190	28
St. Julien, 1858 ..	9·84	450	172	1,860	280	56
Vin Ordinaire ..	6·99	500	78	3,500	310	87
Rhine.						
Hock Castle I. ..	6·63	440	..	1,540	160	56
Rudesheimer ..	13·32	440	118	1,280	120	50

465. To find (approximately) how many fluid ounces of any of these wines contain an ounce by weight of absolute alcohol, divide the corresponding number in the second column into 100; thus, in the case of Champagne, $100 \div 7{\cdot}95 = 12{\cdot}6$, therefore, about $12\frac{1}{2}$ fluid ounces of Champagne contain one ounce by weight of alcohol.

466. Like wines, MALT LIQUORS consist of water, alcohol in moderate amount, free acids, sugar, salts and extractive

matters. They ought to be, essentially, the result of the alcoholic and acetous fermentations of an infusion of malted barley, flavored with hops alone. Their action on the system is such as might be anticipated from their ingredients, namely, stimulant from their alcohol; tonic and sometimes narcotic from their hops, antiscorbutic from their salts and free acids and fattening from their sugar and other carbo-hydrates included in their extractive matter. Taken in excess, they produce a condition of plethora and redundance of fatty tissue; oxalic and uric acids are formed, leading to gouty and other constitutional affections. In moderation they are valuable subsidiary articles of food; and (as is also the case with wines) their use should be encouraged in preference to that of spirits, in cases where alcoholic drink of some kind is taken through necessity, habit or inclination.

467. The qualities of **good ale** or porter are clearness, effervescence and agreeable taste; specific gravity ranging from 1,000 to 1,005 in ale, 1,004 to 1,008 in porter; strength from five to nine per cent. of alcohol by volume; acidity from 120 to 200 grains, reckoned as acetic anhydride, per gallon in ale, (0·1714 to 0·2857 per cent.), as much as 250, (0·3571 per cent.), being allowable in porter; solid residue, dried at 230° F., about 1,800 grains per gallon in the former and 3,000 in the latter; finally, freedom from adulteration.*

468. The **specific gravity** is most conveniently and with sufficient accuracy ascertained by dividing the weight of the contents of a specific-gravity bottle filled with the sample by the weight of an equal volume of distilled water; the liquor having first been exposed to the air for some time and repeatedly stirred so as to ensure freedom from carbonic acid gas, which is almost always present to the extent of one or two cubic inches in an ounce. The error arising from weighing distilled water and the liquor at the same temperature, without reduction to standard, is in this case, where the proportion of alcohol is small, insignificant.

* The report on malt liquor required by the Government of Madras includes:—1. specific gravity, 2. extract gravity, 3. alcohol per cent. by volume, 4. acid per cent.

469. To determine the **alcohol** distil, as in the case of spirits, 8 measured ounces, until two-thirds have come over. Make up distillate to original bulk with pure water and take the specific gravity of the dilution as described in (468). The following Table gives the means of finding the per-centage of alcohol by volume corresponding to each density :—

Density.	Alcohol by volume	Density.	Alcohol by volume.	Density.	Alcohol by volume.
9,866	10·0	9,912	6·2	9,935	4·5
9,879	9·0	9,916	6·0	9,942	4·0
9,891	8·0	9,918	5·8	9,949	3·5
9,904	7·0	9,922	5·5	9,956	3·0
9,907	6·7	9,926	5·1	9,970	2·0
9,910	6·5	9,928	5·0		

470. To obtain accurate results by this method both distilled water and diluted distillate should be cooled to 60° F. This being often difficult and inconvenient, it will be better to operate in the manner described for wine (451).

471. The **acidity** is determined by the standard alkaline solution; multiplying the number of cubic centimeters required for neutralization of half an ounce by 25·18.* The result is grains of acetic anhydride per gallon. Pure dry sodium carbonate may be used for the same purpose as explained before (424). The liquid left in the retort after distillation (469) evaporated to dryness at 230° F., will give the **solid** residue, the weight of one-third of which multiplied by 40 gives grains per gallon; and the **ash** is obtained from the same. The latter consists principally of chlorides and phosphates of the alkalies and alkaline earths. The difference between solids and ash is called the "malt extract."

472. It is sometimes desirable to ascertain the **original density** of the wort or malt infusion from which the liquor was prepared by fermentation. For this purpose 12 ounces are distilled and the density of the distillate diluted to original bulk taken. The difference between 1,000 and this density, corrected for acetic acid (474) is the *spirit indication*. The *extract gravity*, that is, the density of the residue in the retort diluted to original bulk, is then found. The latter number added to that corresponding to the spirit indication, as found in the following table, is the *original density* :—

* 0·0051 multiplied by 15·43 to bring grams to grains and the product by 320, the number of half-ounces in a gallon.

Spirit indication.	0·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	..	0·2	0·6	0·9	1·2	1·5	1·8	2·1	2·4	2·7
1	3·0	3·3	3·7	4·1	4·4	4·8	5·1	5·5	5·9	6·2
2	6·6	7·0	7·4	7·8	8·2	8·6	9·0	9·4	9·8	10·2
3	10·7	11·1	11·5	12·0	12·4	12·9	13·3	13·8	14·2	14·7
4	15·1	15·5	16·0	16·4	16·8	17·3	17·7	18·2	18·6	19·1
5	19·5	19·9	20·4	20·9	21·3	21·8	22·2	22·7	23·1	23·6
6	24·1	24·6	25·0	25·5	26·0	26·4	26·9	27·4	27·8	28·3
7	28·8	29·2	29·7	30·2	30·7	31·2	31·7	32·2	32·7	33·2
8	33·7	34·3	34·8	35·4	35·9	36·5	37·0	37·5	38·0	38·6
9	39·1	39·7	40·2	40·7	41·2	41·7	42·2	42·7	43·2	43·7
10	44·2	44·7	45·1	45·6	46·0	46·5	47·0	47·5	48·0	48·5
11	49·0	49·6	50·1	50·6	51·2	51·7	52·2	52·7	53·3	53·8
12	54·3	54·9	55·4	55·9	56·4	56·9	57·4	57·9	58·4	58·9
13	59·4	60·0	60·5	61·1	61·6	62·2	62·7	63·3	63·8	64·3
14	64·8	65·4	65·9	66·5	67·1	67·6	68·2	68·7	69·3	69·9

473. For **example**, suppose the corrected density of diluted distillate to be 990·3, the spirit indication will be 1000—990·3=9·7, and the corresponding figures taken from the table will be 42·7. This added to 1014·3, density of diluted residue, gives 1057·0 as the specific gravity of the wort before its sugar began to be converted into alcohol.

474. But in most malt-liquors and especially in those which have been ill-brewed or long kept, some of the alcohol has become oxidized into acetic acid. Some of the loss of density which the wort has undergone in conversion into ale or porter is due, therefore, to the presence of this acid, and a **correction** must be made in proportion to the amount of the latter. Having ascertained by means of the standard alkaline solution, the quantity of acetic acid in a known *weight* of the liquor, the percentage by weight of acid is easily calculated. The following Table gives a corresponding number, which is *added* to the spirit indication before using the table previously given(472.)

Percentage of Acid.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	..	0·02	0·04	0·06	0·07	0·08	0·09	0·11	0·12	0·13
1	0·14	0·16	0·18	0·20	0·21	0·22	0·23	0·25	0·26	0·27
2	0·27	0·29	0·31	0·33	0·34	0·35	0·36	0·38	0·39	0·40
3	0·39	0·41	0·43	0·45	0·46	0·47	0·48	0·50	0·51	0·52
4	0·52	0·54	0·56	0·58	0·59	0·60	0·61	0·63	0·64	0·65
5	0·65	0·67	0·69	0·71	0·72	0·73	0·74	0·76	0·77	0·78
6	0·77	0·79	0·81	0·83	0·84	0·85	0·86	0·88	0·89	0·90
7	0·90	0·92	0·94	0·96	0·97	0·98	0·99	0·01	1·02	1·03
8	1·03	1·05	1·07	1·09	1·10	1·11	1·12	1·14	1·15	1·16
9	1·15	1·17	1·19	1·21	1·22	1·23	1·24	1·26	1·27	1·28
10	1·29	1·31	1·33	1·35	1·36	1·37	1·38	1·40	1·41	1·42

475. The **adulterations** to which malt liquor is liable are very numerous, but a few only require mention here. *Water* in excess will be detected by deficiency of alcohol (469), and low extract gravity (472), the latter in good ales rarely falling below 1,010, or 1,012 in good porters. *Alcohol* added either directly or by mixing sugar with the wort is common in the beer brewed in this Presidency and reaches 10·5 per cent. by volume in some samples. It is easily detected by distillation (469). *Chalk* or *sodium carbonate* is often put into liquor which has become sour. This adulteration may be suspected if the acidity is much below the average, and may be detected by distilling the liquor, after evaporation to syrupy consistence, with sulphuric acid; the acetic acid which had combined with the base will distil over in considerable quantity. It is possible that *cannabis* and similar drugs are sometimes added in this country, but they have not been detected in this Presidency. They would be sought for in the dry extract as before mentioned (443), and the latter remark applies to *capsicum* and *cocculus indicus* also. The ordinary public-house adulterations do not need to be noticed for our purpose.

476. In this place **cider** and **perry** may be briefly noticed. The former is a fermented liquor prepared from the juice of apples. The percentage of alcohol by volume ranges from 5 to nearly 10 per cent.* It is a wholesome drink, rarely containing any impurity except lead, accidentally derived from the presses &c. This, if present, will be detected by evaporating to dryness, incinerating, dissolving in dilute nitric acid; and precipitating with sulphuretted hydrogen, or testing the solution with dilute sulphuric acid: the former precipitate being black; the latter white and soluble in ammonium acetate. Perry, (prepared from pears), is also a wholesome drink, containing from 5 to 9 per cent. of alcohol by volume.

477. The ALKALOIDAL DRINKS in common use are *coffee*, *tea* and *cocoa*. The last differs from the other two in possessing directly nutrient properties in addition to those

* An analysis of common laborers' cider gave in parts per 1,000 by weight:—water 938·36, alcohol 40·00, sugar 10·00, ash 3·00 volatile acid (as acetic) 1·55, fixed acid (as malic) 3·35, extractive matters 3·14.

due to its salts. The former owe their physiological action to a certain alkaloid, called indifferently caffeine or theine.

478. **Coffee** contains, in the raw state, about 0·75 per cent. of caffeine, (reduced to 0·25 in the process of roasting), 10 to 13 per cent. of fat, 13 of nitrogenous substances, and between 6 and 7 of salts—potassium, magnesium and calcium in combination with phosphoric acid and chlorine. The effect of the alkaloid is to stimulate the nervous system. It increases the action of the heart, kidneys and skin, its diaphoretic property aiding its generally stimulating effects in rendering its use desirable in hot climates and hot weather. There is good reason to believe that it helps the system to resist malaria, and a strong infusion of coffee should, therefore, always precede an early journey or march, especially in malarious districts.

479. Coffee is **prepared** for use by roasting, grinding and infusing. Adulteration being out of the question here, where the consumer buys the raw seed, it is only necessary to see that the "berries" are not withered or mixed with dirt of any kind. The *roasting* should be performed at a temperature not exceeding 320° F., and a small quantity of oil, butter or ghee is generally used to prevent burning. In this process the coffee increases in bulk, loses from 15 to 25 per cent. of its weight, and acquires its characteristic aroma, from the development of a principle called *caffeone*. This is readily dissipated on exposure to the air; it is, therefore, desirable that small quantities only should be roasted at one time and that, after roasting, the coffee should be kept in an air-tight tin or bottle. The roasted berries are *ground*, either in a mill, or, as is more usual here, in a mortar. The *infusion* should be made with boiling water which, if complete extraction of every thing soluble be not required, may simply percolate once through the powder, in a suitable vessel; thus avoiding the necessity of straining or otherwise clearing the infusion. Coffee should not be boiled; as, although its soluble constituents are thus more completely extracted, the aroma is thereby diminished. Perfect extraction may be insured by using for the infusion water in which the residue of a previous infusion has been well boiled. When percolation is not practicable the grounds can be made to subside more rapidly by adding the white of egg to the liquid, or by pouring a little cold water into it from a height. 1¾

ounces of freshly roasted coffee should make one pint of infusion.

480. Coffee must generally be **selected** according to the appearance of the berry, and the odor and flavor of the same when roasted and ground and of the infusion prepared from it. Its physiological action on the nervous system, however, depending upon the presence of its alkaloid, it is sometimes desirable to ascertain the per-centage of the latter.

481. The **caffeine** is isolated in the following manner:—Mix with a decoction of the powdered coffee, (roasted or unroasted according to the information sought), a solution of tribasic lead acetate. The acid with which the alkaloid is combined is precipitated along with some coloring matter. Pass sulphuretted hydrogen through the filtered mixture, to remove lead from solution; filter, evaporate to a small quantity, and the caffeine will crystallize out in white, silky, acicular crystals.*

482. The alkaloid of **tea**, sometimes called *theine*, is identical with caffeine. The physiological action of tea will, therefore, be the same as that of coffee; the chief differences, for our purpose, between the two being the greater proportion of alkaloid in the former and the presence of a considerable amount of tannin. The characteristic aroma of tea is developed by heat during the process of manufacture. Teas are divided into two classes —*green* and *black*; both the products of the same plant, but differently prepared for use. The former contains a larger proportion both of caffeine and of tannin than the latter and less cellulose: their composition in other respects being nearly identical. Green tea is comparatively little used, owing to its high price, its powerful action on the nervous system when genuine, and its great liability to pernicious adulteration.

483. There are three great varieties of **black tea**. In the fourth or fifth year of the plant's age. or later, the young shoot is plucked as soon as three leaves have appeared on it. The uppermost leaf, scarcely expanded, when dried gives *pekoe*; the second, about 36 hours old, *souchong*;

* The empirical formula is $C_8H_{10}N_4O_2+H_2O$. Caffeine increases reflex excitability, and in poisonous doses produces tetanus, its action resembling that of strychnine. 0·005 grm. injected hypodermically into a frog excited tetanus; 0·120 grm. introduced into the jugular of a rabbit, or 0·200 grm. into that of a dog or cat, had the same effect.

the third, of 48 to 60 hours' growth, *congo*. A fourth leaf is sometimes plucked, and yields *bohea;* but the proportion of caffeine diminishes from the topmost leaf downwards and is insignificant in this last variety which is rarely brought to market in the present day. All three varieties are plucked and dried together and separated subsequently by sieves of different sized meshes; pekoe and souchong passing through the first sieve, leaving congo behind, and being separated from each other by a further sieving. It will be inferred that the different kinds of black tea may be distinguished by the different sizes of the leaves expanded by infusion.

484. In **composition** the only important points in which teas differ are flavor and amount of alkaloid. The *ash* is about 5 per cent. of the weight and consists of the alkaline and alkaline-earth bases, with iron and manganese, in combination with chlorine, carbonic, phosphoric and silicic acids. The *caffeine* is very variable in quantity in different teas, the Indian samples containing more than those from China and Japan. The per-centage ranges from 1 to more than 6.

485. In **choosing** tea the fragrance and taste of the infusion are the best guides. The dry tea should be free from dirt, from excess of stalk, from the dust of broken-up leaves and from red leaves.

486. The main points to be observed in the **preparation** of tea are that the water should be and remain as little as possible below boiling point and that the infusion should not be too long continued. For the former purpose an earthenware tea-pot, well heated before the tea is put in and protected afterwards with a *loose* quilted cover, is best adapted. The water must always be boiling when poured upon the tea, but it should not have been kept boiling long. Fifteen or twenty minutes is the longest time which should be allowed for infusion, and the flavor of choice tea is best appreciated when the process lasts but five minutes, although less caffeine is then extracted. Soft water gives tea of a deeper color than hard, but the flavor is not so good, and the same remark is applicable to hard water softened by adding sodium carbonate. The best water is said to be one of 4° to 7° permanent hardness; $1\frac{1}{4}$ oz. of good tea (about $2\frac{1}{2}$ tea-spoonfuls) should make one pint of infusion.

487. The **adulterations** of tea are of two kinds—the substitution of leaves of other plants, and the introduction of exhausted tea-leaves re-rolled and dried. The former is detected by examination of the expanded leaves; the genuine leaf being recognized by a margin serrated incompletely, the parts near the stalk being entire, and by an unveined portion between the edge and the reverted extremities of the primary veins. Exhausted leaves may be known by their yielding less soluble matter and less caffeine than they ought. A known weight of the suspected tea is exhausted of its soluble matter with boiling distilled water and the leaves are dried and weighed. Black tea should lose from 29 to 45 per cent. of its weight; green, from 40 to 48. The caffeine may be determined by the process already described (481). It is recommended to obtain the crystals, in the case of tea, by sublimation from the solution evaporated to dryness at a low temperature. The ash of tea should not exceed 8 per cent. of the weight of the sample dried at 100° C.; and at least 3 per cent. of the ash should be soluble in water. Tea from exhausted leaves will be deficient in soluble ash.

488. As has been already remarked, **cocoa** differs from tea and coffee in being eminently nutritious. The "beans" of the *theobroma cacao* or their integuments are the source from which the article is obtained. Its alkaloid is *theobromine** which has properties similar to those of caffeine and is present to the extent of 1·2 to 1·5 per cent. It contains from 13 to 18 per cent. of other nitrogenous matter and 48 to 50 per cent. of a solid fat. Its proportion of phosphoric acid is also high. Its characteristic aroma is developed by roasting.

489. Cocoa is **prepared** for use in three different ways. Either the whole seed, after roasting, is beaten or ground into a paste, which, mixed with starch, sugar &c., forms the ordinary "cocoas" of the shops; those containing starch requiring boiling with milk or water for efficient preparation, while those mixed with sugar alone need merely to have boiling milk or water poured upon them. Or, the bean is deprived of its husk (which constitutes

---

* $C_7H_8N_4O_2$, which gives the formula of caffeine if H be replaced by CH_3 (methyl).

about 11 per cent. of its weight) and broken up into "cocoa nibs," which are boiled in water and produce a decoction more digestible than the other preparation. Or the seed, shelled and ground into a paste between hot rollers, is mixed with sugar and flavored with vanille, and sometimes cinnamon and cloves, forming "chocolate."

490. **Adulterations**, organic and inorganic, are very numerous. Flours and starches are often added, but to a certain extent the addition of such substances is desirable or necessary, and cannot be considered fraudulent unless the quantity be excessive. This question must be decided by microscopical examination, by which the various starch-granules may be detected and distinguished. Brick-dust and ferric oxide have been found. They may be detected by examination of the ash; the former resisting acids, the latter dissolving and giving characteristic reactions. The nibs often contain more or less of the husks of the seeds. Samples are considered adulterated if the cocoa-fat, (determined by extraction by ether), is less than 30 per cent.

491. A few lines may here be devoted to **mate** or Paraguay tea, consisting of the dried leaves of the *Ilex paraguayensis* or Brazilian holly. Its active principle is caffeine, the amount of which is variously estimated, from 0·13 to 1·20 per cent. Its action is stimulant and restorative.

492. **Tobacco** is not a food, but this appears to be the most suitable place to notice it briefly. Its active principle is *nicotine*,* which is present in the dried leaf in quantity varying from 1·5 to 8 per cent. Virginia tobacco contains most, the Maryland, Havannah and Indian† kinds least. Tobacco, smoked, acts as a sedative, soothing nervous irritability and allaying appetite for food. Its use in moderation in this way is certainly harmless, moderation varying with the idiosyncrasy of the individual and the proportion of nicotine in the tobacco. In excess it weakens the heart's action, produces nervous tremors and impairs vision. Adulteration being in this country

* $C_{10}H_{14}N_2$.

† Mr. Broughton found good Trichinopoly tobacco to contain 2·52 to 4·55 per cent. of nicotine. The strongest examined was from Cuddapah, with 7·44. The mean yield of Indian tobaccoes was 3·25, higher than Manilla or Havannah which contains about 2·25.

highly improbable, the only point to be determined is the percentage of alkaloid.

493. To isolate the **nicotine**, boil the leaves in distilled water, which dissolves the alkaloid combined with citric and malic acids. Strain; evaporate to consistence of syrup and mix with alcohol. The mixture separates into two strata: the upper, alcoholic, containing the nicotine salts; the lower, aqueous, retaining most of the extractive matters. Draw off the former and shake it well with solution of potash to take the acids, and with ether to dissolve the liberated nicotine. Decant the superficial ethereal solution, evaporate the ether; nicotine remains, an oily fluid, with a pungent, tobacco-like odor, colorless when pure, but altering on exposure to the air.

494. Tobacco and many other vegetable substances are extensively used as **masticatories.** All stimulate the salivary glands; which, however, seem to adapt themselves to the increased demand, so that it is difficult to indicate any mischief to health attributable to the practice of "chewing," although on æsthetical grounds it is highly objectionable. In India the commonest masticatory is the *pán-supári* or *betel-nut*, a combination of the leaf of the betel pepper with the nut or seed of the areca palm, to which lime is generally added. The nux vomica is not uncommonly chewed without apparent injury. Opium is smoked or eaten*: cannabis is eaten, drunk, or smoked, and excessive indulgence in it is a frequent cause of admission into Lunatic Asylums in India. With the exception of these last substances it does not appear that the sudden and complete deprivation of any, as in the cases of prisoners or soldiers in the field, is attended with anything more serious than inconvenience and discomfort.

---

* It is believed by the natives both of India and China that opium smoking and eating are protective against malaria.

CHAPTER V.

SOILS.

495. The SOIL on which a house, tent or other dwelling is placed may influence the sanitary condition of the inhabitants, through the *climate*, through the *air* breathed and through the *water* used for domestic purposes.

496. The conformation of the ground, its relation to the neighbourhood as regards position and elevation, the vegetation which it supports, the permeability of the soil and sub-soil by water, their capacity for absorbing and their power of radiating heat, and the color of the surface are the circumstances which affect the **climate** of the place. Malarious or other miasmatic emanations may contaminate the **air**, and the **water** will be affected by the soluble substances, organic and inorganic, which it takes up in percolation through the soil.

497. Both the temperature and the humidity depend, to a great extent, on the **conformation** of the ground: including, if the place be uneven, the relative extents of high land and valleys; the degree of elevation of the highest parts; the forms, depth, width, slope, and nature of the sides of the valleys; the position and direction of the lines of drainage: and, if the level be uniform, the degree of slope and the capacity and direction of the water courses. Thus, as hills cool by nocturnal radiation more rapidly than lower land, a current of cold air will flow down a valley or ravine by night, depressing the temperature at the outlet. If the outlet be narrower than the main valley or ravine, so that the water draining from above has not sufficient means of escape, dampness will be added to coldness and alternations of temperature. As a rule, positions at the top of a slope will be found best; their temperature being lower and more uniform and free drainage preventing accumulation of water in the soil. As the conformation of the surface of a district is generally a consequence of its geological structure, a knowledge of the latter often affords an indication of the nature of the

local climate and its probable effect on health. Thus good sites may be expected where granitic or metamorphic or trap rocks prevail; because these generally imply elevated positions, affording moderate temperature and free natural ventilation, as well as slopes favorable to drainage and consequent absence of excessive humidity. Deposits of clay, on the other hand, are generally flat, so that air stagnates and water lodges.

498. Closely connected with the form of the ground itself is its **relative position** with respect to the neighbourhood. In a hilly country a site may be unhealthy, owing to its being so surrounded by hills that ventilation is impossible and the air is stagnant; and, as before observed, narrow valleys or ravines may become channels for currents of cold air, which chills at night a place so situated as to be exposed to its influence. A lower degree of the same cooling effect of elevated land may act beneficially when the more rapid radiation of heat from the latter produces a diffused cool breeze instead of a cold draught. On the other hand a low rocky hill, radiating at night the heat absorbed during the hours of sunshine, often renders places at its foot permanently hot and, if other causes combine, unhealthy. A site, again, may be sheltered from the action of a prevailing wind by the intervention of a hill or range of hills—a circumstance which may be useful, as when the wind blows over a marsh, or injurious, as when a sea-breeze or other refreshing current of air is intercepted. This power of hills to shelter from, or alter the apparent direction of, the prevailing wind should be borne in mind when we are choosing a site for temporary or permanent occupation.

499. Relative position has to be considered with reference to moisture also. A position at the foot of hills may suffer by excess of water flowing from them; either directly through humidity due to deficient drainage or indirectly through malaria produced by exuberant vegetation. In a plain itself a part depressed below the general level may be damp in consequence of the tendency of the drainage: and in this way soils which would under ordinary circumstances be dry and healthy (as gravels) may be in some instances damp and productive of disease.

500. So far as the mere process of growth is concerned, **vegetation** can be productive of good effects only: but

exuberant growth involves excess of decomposing vegetable matter, which, under the influence of heat and moisture, is almost universally believed to be the source of malaria. On the whole, the good effects of vegetation exceed the bad. Herbage intercepts much of the solar heat and, by favoring gradual evaporation, cools and equalizes the temperature. Retaining a large proportion of the rainfall, it regulates the humidity of the atmosphere while, by preventing too rapid drainage, it helps to maintain the water-supply in the soil. Unirrigated crops act similarly, and neither they nor herbage are ever injurious to health. Shrubs and trees have the same effect upon temperature and humidity; but the former always, and the latter, especially the palms, during the earlier stages of their growth, are likely to obstruct seriously the free circulation of air. In the neighbhourhood of dwellings, therefore, brushwood is objectionable and should be kept cut low or be altogether removed, while full-grown trees should have all their branches within 10 or 12 feet of the ground cut off; unless, as sometimes happens, a belt of trees shelters a site from a cold wind or intervenes between a place and a source of malaria. Finally, since the sanitary effect of herbage and of forest trees is almost always good, the growth of the former should be encouraged to the utmost, and the latter should be planted judiciously in and about every inhabited place. In districts where the destruction of timber has raised the temperature and diminished the rainfall, the injury done to the climate and sanitary condition of the population should be repaired as far as possible by plantation.

501. Almost all soils are permeable in some degree by water; but the power of absorbing and retaining it varies within wide limits, depending on the nature of the surface and of the soil itself. In considering **permeability** the chief point, in relation to health, is the retention of water in excessive quantity by the soil ; producing dampness of the air and reducing temperature in all cases, and generating malaria if the other conditions necessary to its production, heat and the presence of dead vegetable matter, are fulfilled. Such rocks, as *trap*, *granite*, *clay-slate* and the harder *limestones*, and *dolomites*, are practically impermeable and irretentive of moisture, not only in consequence of their structure, but because they generally present a slope

which prevents the lodgment of water on their surface. On the other hand, *clays* are commonly flat, so that water lies upon them; and, though they are little more permeable than the harder rocks, saturation proceeds to the utmost. In some cases clays absorb and retain as much as 10 per cent. by weight of water. Through *sandstones*, *chalk*, and still more through loose *sand*, water passes readily and rapidly; but it must be remembered that the admixture of even a small proportion of clay impairs the permeability of sand and increases its retentiveness. *Humus*, or decaying woody fibre, absorbs and retains from 40 to 50 times as much water as sand. The old lacustrine deposits, commonly called *cotton soil*, are highly absorbent and retentive; and so also, though to a less degree, is the soil resulting from disintegrated gneiss, which yields much of our *red soil*. *Laterite* is permeable and irretentive, and *gravel* eminently so. Lastly, the roots of living *vegetation* impede the passage of water through a soil.

502. To apply these facts to the **effects** of permeability on health, it may be laid down, as a general rule, that the soils which are driest, whether because the water which falls on them runs off immediately or because it passes through them rapidly, are also healthiest. Where water lodges, on or in the ground, the air is damp and cold; and, as a consequence, there is a tendency to catarrhs and rheumatic affections, to phthisis and to malarious intoxication. Where the soil is dry the air also will generally be dry, the inhabitants will be free from those diseases and in other respects will be in better health. Hence the hardest soils, from which the water runs off, and the most permeable through which it passes rapidly, will (other things being equal) be the healthiest. A gravel hill or slope combines both these advantages.

503. There is an apparent **exception** to the rule that permeability of a soil implies healthiness. Gravel, for instance, may occupy a hollow either in hard rock or in clay, which holds the water in: and in this way a material naturally permeable may become saturated with moisture. It may be added that even a permeable soil, retaining water for but a short time, may generate malaria if organic matter be present.*

* The sandy soil of the Landes in Burgundy illustrates this latter exception.

504. The nature of the surface and of the ground beneath it determines the power of **absorbing heat**; and in this way affects, either by conduction or radiation, the temperature of the place. The air immediately in contact with hot ground becomes heated, but rises and is replaced by a cooler stratum. The most absorbent soils, therefore, being the hottest, will be most productive of air-currents by conduction and convection. The best absorbents, again, are the best radiators, giving out most rapidly the heat which they have received. During the day both processes are going on together; but in the evening, when solar heat is diminished, and at night when it is absent, radiation alone proceeds, and those soils which are most absorbent of heat cool most rapidly. In warm weather compact soils are on the average warmer than the loose; in winter, or on a fall of temperature in hot weather, colder. In warm weather compact soils are warmer by day and colder by night than loose soils; and are subject to greater fluctuations of temperature.

505. The color of the **surface** affects absorbent power of luminous, but not of obscure heat, the darker shades absorbing more heat than the lighter; but color has no effect on radiation. The *slope* of the surface also, in relation to the sun's position during the hours of greatest heat, deserves consideration; reflection of heat-rays being greatest and, therefore, absorption least, when the angle of incidence is greatest. Herbage is unfavorable to absorption and promotes coolness in this way, besides its action in cooling by evaporation and in converting solar heat into vegetative force.

506. The **material** of which the soil is composed influences powerfully the degree of absorption and radiation. The following Table shows numerically the power of absorbing heat possessed by some ordinary soils:—

Sand, with lime ...	100·0
Pure sand	95·6
Light clay	76·9
Gypsum	73·2
Heavy clay	71·1
Clayey earth	68·4
Pure clay	66·7
Fine chalk	61·8
Humus	49·0

It follows that in cooler climates clays and cultivated soils are cold; in warmer climates cool: and, on the other hand, that sandy soils are hot, and hotter in proportion to the darkness of their color.

507. Two **ranges of temperature** are observable in soils—one diurnal, the other annual. The former extends to a depth varying with the solar heat and the nature of the ground, rarely more than four feet in temperate climates. The distance from the surface at which the temperature is uniform and equal to the mean annual temperature is said to range from 57 to 99 feet. Observations on these points in India are much needed.

508. The **effects** of absorptive power upon health are those of temperature generally; the most absorbent soils being the most freely radiant. In estimating these effects, however, other things have to be considered besides degree of solar heat and radiant power of the soil. Aqueous vapour in the atmosphere absorbs the radiant heat, which through dry air would pass into space; and this again is radiated to dwellings and their inhabitants; so that aerial humidity also has to be taken into account. Water in the soil, again, being evaporated by the heat absorbed, retains much of the latter as latent. Thus marshy soils render latent most of the heat which they absorb: and in this way their poison is not unfrequently antagonized or neutralized by the cold which they themselves generate.

509. The **color** of the surface may be important in its result upon the sight. As blindness may be caused by the prolonged effect of snow, so the glare of white or of light-colored ground may be disagreeable and even injurious in countries of bright sunshine. Green being the hue most refreshing to the sight, trees and grass are to be encouraged in places where quartz or other white rock occupies much of the surface; and buildings, instead of being white-washed, should be colored according to the materials available in the locality.

510. Coming now to the effects of soil on health through the **air**, we shall consider them under the two heads of *malaria*, (which always is used in this Manual in its original meaning of the marsh or paludal poison) and other *miasms*.

511. Of the nature, chemical or physical, of **malaria**—the poison which produces intermittent fevers, neuralgias

and other well-marked diseases—nothing is known with any certainty; and it would be useless, for the present purpose, to discuss it. Most physicians are agreed as to its origin. It is generated by vegetable matter in the soil, undergoing slow decomposition, under the influence of moisture and a certain degree of temperature not less, it is supposed, than 67° F. (19·3 C.)* It is probably not gaseous, because it appears incapable of ascending by diffusion to very great elevations, and because a belt of trees is often known to shelter from its influence. It can enter the blood and produce its poisonous effects, either by the air breathed or by the water drunk. It can spread, in calm air, through a cube of 1,400 to 2,000 feet; *i.e.* to a distance of 700 to 1,000 feet from its source. It is carried by air currents to distances of 1 or 2 miles; and considerably farther according to some authorities. Water opposes its spread, salt-water more effectually than fresh.

512. Although the causes given above are believed to be invariably present in malarious localities, they are sometimes co-existent in places where paroxysmal fevers and other effects of paludal intoxication are unknown. There are two well-marked **exceptions** to the rule that sufficient heat, moisture and decomposing vegetable matter in the soil generate malaria. Peaty soils fulfil these conditions, (unless it be supposed that their well known antiseptic properties prevent the decomposition of the organic matter which they contain), but in boggy countries, as in Ireland for instance, endemic paroxysmal fevers are unknown. Secondly, tracts regularly covered by the sea at each flow of the tide are not malarious, perhaps because the products of decomposition are washed away before they have reached the stage in which they become poisonous. Besides these two exceptions, anomalous cases have been observed in various parts of the world where malaria might have been expected to be present and was not.

513. Knowing, then, the conditions necessary for its generation, it is easy to infer the places where it is likely to be **prevalent**. These may be briefly enumerated:—

* The air of marshes contains much organic matter, which is not destroyed by ozone; including much animalcular life. Some attribute its poisonous effects to the spores of algoid plants which are always present.

Marshes, in hot or temperate climates, whatever be the mineral constituents of the soil, containing dead organic vegetable matter to the extent of from 10 to 45 *per cent.* and abundant moisture, will be generative of malaria. Positions at the *foot of hills* which supply abundance of water are often unhealthy, exuberant vegetation being accompanied by accumulation of vegetable débris in the soil. The apparently dry *beds of nullahs* and ravines generally have water at no great distance from the surface and often contain much decaying vegetation. *Sandy plains* with an impermeable substratum of rock or clay a few feet from the surface, which holds up water and keeps the soil saturated, may be highly malarious although bare of vegetation, owing to the presence of the decaying remains of previous vegetable growth. In some, vegetable matter, silicious particles and an oxide or salt of iron become concreted into a nearly impermeable stratum, from which the over-lying water slowly dissolves out the organic material and produces malaria. *Alluvial soils*, (which constitute nearly one-third of the soil of this country), often consist of permeable beds alternating with impermeable strata of clay, retaining moisture in contact with abundance of decayed vegetation; and these are undesirable sites, though it is impossible always to avoid them. The *deltas* of large rivers are of this nature. *Salt marshes* if only occasionally overflowed by the sea are unhealthy. *Newly disturbed soil*, as ground brought into cultivation for the first time or cleared of brushwood by up-rooting, is very likely to be malarious. Even *rocks*, as trap, gneiss and granite, when softened by disintegration, may admit water and organic matter into their substance by slow percolation and so generate malaria. It is improbable that their mineral constitution has any share in the production of this effect; but some have thought differently, and Heyne attributed the Mysore fevers to the decomposition of rocks containing ferruginous hornblende. Lastly, *irrigated lands*, as rice fields, fulfil the conditions for the generation of malaria, and in some countries are virulently unhealthy. In the Southern United States, for example, the rice plantations are almost uninhabitable, except by the black or mixed races, during the heat of summer. In this country Mr. Cornish has pointed out that rice fields exposed to sea air are not sources of malaria, but that irrigation is not innocuous in

inland districts. The proximity of rice fields or positions to leeward of them should be avoided for human habitations as far as possible.

514. The **precautions** and **remedies** indicated by a soil which there is reason to believe to be malarious are—thorough drainage; cutting down to the impermeable sub-soil, if there be any, and in all cases deep enough to withdraw moisture from the stratum which contains decaying vegetable matter; raising the dwellings on solid basements three feet or more from the ground, or (better still) on posts or arches, admitting free passage of air beneath; interposing a belt of trees or a piece of water kept at a constant level between a site and an obvious source of malaria; excluding, especially at night, wind blowing from a malarious quarter; (when this is impracticable, as when it is necessary to sleep in the open air, the use of mosquito-curtains is said to be beneficial); avoiding disturbance of the soil by the clearing away of brush-wood from a temporary position and choosing the hotter hours of the day rather than the morning or the evening for the work if the position is to be occupied permanently; care to obtain drinking-water from a source uncontaminated by decomposing organic matter; selection of sites as elevated as circumstances allow—because, though malaria is not unknown even at a height of 6,000 feet above sea-level, its power is diminished by elevation, owing to the diminution of temperature.*

515. Besides malaria, there are **other miasms** which may be generated or stored up in the soil, becoming disengaged from it either gradually and uniformly or being forced from it in greater quantities at certain times than at others, by the rise of the subterranean water or by the action of heat. Carbonic acid, marsh-gas and sulphuretted hydrogen, sewer-gases generally, the specific poisons of cholera and enteric fever are those which demand notice.

516. The air in soils is almost always rich in **carbonic acid**, sometimes includes **marsh-gas**, and occasionally (when sulphates are present) **sulphuretted hydrogen**.* The proportions of these gases which pass into the atmos-

* The elevation necessary for security from malaria varies in different countries from 400 feet upwards.

phere by diffusion are so small, however, that their presence in soils may be considered practically unimportant.

517. Putrefying organic matter in the soil and leaky drains or cess-pools will evolve **sewer-gases** and their accompanying organic vapors, which penetrate the soil and enter unprotected dwellings through the ground on which they stand. In like manner the **specific poisons** generated from the decomposing excreta of the sick may enter the air of the soil from the surface, from cess-pools or from drains, and may travel from their source to distances varying with the nature of the ground. Cholera and enteric fever are by many supposed to be thus propagated to a distance from their foci through the air which the soil contains.

518. The gradual diffusion or intermixture of the ground-air with the atmosphere may, as has been observed above, be disturbed by two things—change in the level of the water in the soil and change of temperature. As the water rises it displaces and forces out the air (with the gases and organic matters which it held in solution or suspension) which filled the interstices of the stratum now occupied by the water. If, on the other hand, the level sinks, the evolution of ground-air will be diminished for the time. Solar heat maintains continual movement, by convection, in the ground-air, thus promoting its intermixture with the atmosphere; and increase of temperature will necessarily increase rapidity of circulation while fall of temperature will diminish it. In houses artificially warmed, again, a powerful draught is created, drawing air not from openings above ground only, but also from the soil. By this means noxious gases and vapors, being or including matters injurious to health, are forced into dwellings both from beneath them and laterally from the soils of yards and streets.

519. The **precautions** desirable in order to guard against miasmata proceeding from the soil are :— drainage, preventing sudden rises in the level of the ground-water and consequent forcing out of noxious gases &c.; raising dwellings from the ground on arches or solid basements; exclusion of air from below by concrete, asphalte or other impervious material in or beneath the floor; and, most important of all, careful choice of site, avoiding, if possible, alluvial soils, and under no circumstances building upon

soils artificially made up of rubbish containing organic matter.

520. The soluble matters in the soil may affect health, though the water used for domestic purposes. Impurities introduced into the system by this means may be either organic or inorganic. The former include the specific poisons of cholera, enteric fever and malarious diseases. This subject, however, as well as that of the inorganic impurities of water, has already been fully considered in Chapter III.

521. Before leaving this part of the subject it is necessary to say something of **ground-water**, which has received much attention of late years, and the effects of which upon health require further study for their complete elucidation. It is the water which is present in a soil in mass, fully occupying the interstices. It is distinct from dampness or moisture, which, however, is, to a considerable extent, dependent upon it; its rise and fall, evaporation from its surface, and ascent of water by capillary attraction necessarily affecting the humidity of the overlying strata. Its distance from the surface of the soil is not only different in different places, but varies in the same place; being dependent (in the former case) upon the nature of the soil, as more or less freely permeable, upon the drainage of the locality and upon the abundance or scarcity of water; in the latter case on the rainfall, on the level of neighbouring rivers or other bodies of water, on the demand for water from wells &c., and, in some degree, on the temperature; so that in a given place its level is changing continually. Unless where restrained by impermeable boundaries, so as to be virtually a subterranean lake (in which case its surface is horizontal and its movement confined to simple rise and fall), it is in a state of continual movement, the direction depending on the line of drainage and the rate upon the permeability of the soil.

522. The effects of the movements and the level of ground-water upon health can easily be inferred from the above description and from what has been already said about the results of moisture in the soil. The rise of ground-water may make a place damp and cold by saturating the soil above it, causing catarrhal and pulmonary diseases; or it may merely supply the moisture necessary

to the generation of malaria or specific miasms. On the other hand its rise may check the production of these poisons by occupying and saturating with water the stratum which contains the organic matter to which they owe their origin. So, too, its fall, after wetting such layers of soil, may stimulate the production of malarious and miasmatic diseases; or its continued depression at a depth below their level too great to admit of their deriving moisture from it may have a highly beneficial effect. If the poison of malaria exists in the ground-air the rise of the ground-water after heavy rain will drive out the poisoned air and produce paludal diseases.

523. The connection between enteric fever and the ground-water is maintained by **M. Pettenkofer** to be more intimate than that described above. He has observed, during epidemics of that disease, that periods of greatest prevalence and virulence coincided with lowest levels of ground-water and especially with a rapid fall succeeding an unusual rise. Such coincidence has not been established elsewhere unless where other conditions concurred. Fall of ground-water in a soil soaked with sewage must be expected to aid in the putrefactive processes which generate the specific poison of enteric fever, whether we regard this as due to sewage simply or to sewage containing the putrefying dejecta of previous sufferers from the disease. Again, low ground-water implies scarcity of water for domestic purposes, concentration of organic impurities in that which is used, percolation of it through a greater depth of sewage-contaminated soil, recourse to impure sources avoided at ordinary times. M. Pettenkofer has not found by chemical analysis that the water at such periods of exacerbation of enteric fever contains an undue proportion of organic matter; he, therefore, denies that the impurity of the water is a factor in the production of the disease; admitting the necessity for the presence of the other conditions, namely, a soil foul with animal impurities, heat, and the existence of the specific germ or poison.

524. His views on epidemic **cholera** are similar. Admitting the possibility of the occurrence of sporadic cases independently of rise or fall of ground water, he maintains that no epidemic occurs without the existence of a porous soil, impure with animal excretions, containing the specific cholera poison, and recently moistened by ground-water. However it may be in Europe, well known facts in this country render these views on the genesis of cholera untenable.

525. It is evident that the **remedies** for the evils due to changes in the level of ground-water are the improvement of existing and the opening out of new passages for the water towards its natural destination. Deep and effective sub-soil drainage will keep the ground-water below the level where danger begins.

526. To state briefly the **sanitary influence** of soils:—impermeable rocks, as granite, gneiss and clay-slate, are

generally healthy: the water from limestone and magnesian limestone strata is often excessively hard, and sometimes unwholesone: chalk, permeable sandstones and gravels are healthy, generally yielding a pure water-supply: sands, if free from organic débris are healthy, but many are malarious; and the water is often highly charged with saline impurities: clays and marshy soils, unless thoroughly drained, are unhealthy: and the worst soil is artificial ground made by the deposit of miscellaneous rubbish.

527. A complete EXAMINATION of a soil for sanitary purposes should include the *conformation* of the surface and its relation to the neighbourhood; the *vegetation* which clothes it; its *temperature*; the amount and nature of the included *gases*; its actual *moisture*; *permeability* by, *absorptiveness* and *retentiveness* of, water; its *mechanical* condition; its *chemical* constitution, inorganic and organic; the level and changes of the *ground-water*. Some of these points require to be mentioned only; others need description in detail; and of the latter some are necessary or practicable only when thorough investigation of a site is desirable with a view to permanent occupation.

528. Observations of the **temperature** of the soil at a depth of 3 feet at the periods of maximum and minimum aerial temperatures are easily made and are useful as indicating absorbent and radiant power and its probable effect on the local climate. Determination of the distance from the surface of the plane of constant temperature is also desirable.

529. The quantity of **gases** occupying the interstices of soils varies with the nature of the latter; some, as the harder rocks, containing little or none, others as loose sands, humus &c., holding large proportions either simply or condensed. It may be roughly estimated by measuring the volume of water necessary to replace the gases in a known volume of the soil. The latter (a) is put into a burette, its natural condition as to closeness and hardness being imitated as nearly as possible. A second burette, graduated, containing water, is connected with the bottom of the first by a clamped elastic tube. Water is permitted to rise gradually through the sample of soil until it just covers it and the quantity required for this purpose (b) is observed; 100 b divided by a is the percentage of air in the given soil.*

530. The **moisture** actually present in a soil at a given time is determined by weighing about 10 grams of the

---

* a (c.c. of soil) : b (c.c. of water used or of gases which it replaces) : : 100 (c. c. soil) : x (gases in 100 c. c.); therefore $x = \frac{b}{a} 100$.

sample before and after drying in a platinum dish, in an air-bath at a temperature of 125° C.; the loss of weight being moisture.

531. Degree of **permeability** is known by digging holes in the soil after a known amount of rain has fallen, or after artificial wetting of the ground; and observing the depth to which the moisture penetrated, immediately and ultimately.

532. Power of **absorption** of water is ascertained by placing 10 grams of the soil, dried at 105°, under a bell-glass with a saucer of water and an equal weight of pure sand similarly dried, the latter being taken as a standard. After 24 hours weigh soil and sand and calculate percentages of increase of weight.

533. Capacity for **retaining** water is roughly estimated by drying a considerable quantity (about 100 grams), saturating it with water in a tin vessel pierced with holes, so as to allow as much as possible to drain off, and then re-weighing. The increase of weight may be compared with that which a similar weight of sand undergoes when similarly treated.

534. Permeability and other qualities of soils depend in a great degree on their **mechanical condition**, by which is meant the manner in which their constituents are aggregated; forming rocks (harder or softer), gravels or sands (coarser or finer), clays, agricultural soils &c.* Those consisting of differently-sized masses are examined by picking out the coarser parts from about 1,000 grams, dried and weighed, washing out the finer particles by a stream of water poured into the upper end of a tube, the lower end of which reaches to the bottom of a cylindrical glass vessel in which the soil under examination is placed) and weighing the residue in the vessel as well as the stones &c. picked out. The difference between the total weight and the sum of the two latter may be taken as clay, the effect of which, as a constituent of soils, has been shown to be of great importance.

* Thus primitive and metamorphic rocks retain about 1 pint of water per cubic yard, loose sand 54 gallons, sandstone 27. Clay retains 10 to 20 per cent. of water, chalk 13 to 17, light loamy soil 20 to 30 and humus 40 to 50.

535. The **chemical constitution** is important chiefly on account of its effect upon the water of the place. The first point, therefore, to be determined is the degree in which the soil is soluble in pure water. For this purpose 10 grams, previously dried, should be stirred with a litre of cold distilled water and left standing for 24 hours. The water, decanted or filtered off, should be examined for organic matter (138), ammonia, free and albuminoid (127, 149), chlorine (154), sulphuric acid (189), lime (157), magnesia (166), phosphoric acid (192), and iron (169). The residue is then treated with dilute hydrochloric acid, filtered, and the filtrate is examined for lime and magnesia. Effervescence on addition of hydrochloric acid will indicate the presence of carbonates, probably of lime and magnesia, and may imply hardness of the water.

536. The distance of the **ground-water** from the surface will always be deserving of observation and measurement, whether M. Pettenkofer's views as to its connexion with epidemic disease be ultimately adopted or not. For this purpose a special well should be dug or selected, covered to exclude direct rainfall, and reserved for measurements of ground-water only. A bar of iron or of wood, graduated metrically or in feet and inches from above downwards, is the best instrument for determining the distance from the surface of the soil to the level of the water. In a small station one such well will be sufficient, but in thickly-peopled towns with many wells, some used more freely than others, several places of observation should be chosen and the mean depth calculated. Measurements should be made weekly and the results compared with rainfall and with the sanitary condition of the population with regard to epidemic and endemic disease.

537. From what has been said it will be easy to deduce rules for the CHOICE of a site, whether temporary as of a camp, or permanent as of a town, a cantonment or a railway station.

538. A good **encamping ground** should be dry, moderately elevated, with sufficient slope to prevent the stagnation of water on or beneath the surface. Good water in abundance should be in the immediate neighbourhood. If the position is near a river, the risk of inundation by sudden freshes should be considered. Ground below the bund of a tank is objectionable, both because it may be

moist by percolation and because of the possibility of inundation by bursting of the bund. The dry bed of a tank should not be chosen, being probably malarious. If there are marshes in the neighbourhood, (the presence of which may be indicated, when careful examination is impracticable, by abundance of frogs, insects, insectivorous birds, paddy-birds and other waders), the camp should be pitched to windward of them. The shade of trees is desirable, but ground covered with brushwood is unsuitable. Spots recently occupied by another party, whether of troops or of civilian travellers, are objectionable.

539. Little can be done in the way of **preparation** of sites for temporary encampment. Surface-drains may sometimes be cut with advantage, and shallow trenches dug round each tent, if heavy rain be present or threatened. Latrine-ditches should be prepared to leeward of the camp —to be filled in with earth before moving on. On established lines of march fixed encamping-grounds are often selected, and their condition requires careful examination before occupying them. Refuse of all kinds left by previous occupants should be removed and burned, and the state of the water-supply examined.

540. The choice of a site for **permanent** occupation should not be made until after a full year's experimental investigation. During this period the meteorology and climate of the place should be carefully observed in the manner which will be described hereafter (chap. IX); the geology of the district examined; the elevations of the hills ascertained. The soil and water should be examined, the fluctuations of ground-water observed and the lines of drainage accurately determined. The health of the observing party will be a valuable indication.

541. A site being chosen for permanent occupation, its **preparation** for buildings &c. will include thorough surface and subsoil drainage, the former by paved surface channels, the latter by drainage pipes laid on or in the nearest impermeable stratum. Brushwood will be removed, with as little disturbance as possible of the soil, the lower branches of existing trees removed, and others planted along the lines of road and the boundaries of compounds. The growth of herbage will be encouraged. Hollows should be filled up with materials free from animal and vegetable matter, care being taken that a permeable

stratum or a drain prevents accumulation of water in them. The point of chief importance is the drainage of the ground, so as to provide not only for the dryness of the soil, but also for the removal to a safe distance of water rendered impure by domestic use.

CHAPTER VI.

DWELLINGS.

542. Protection from the direct action of the sun, from rain, and in cooler climates from cold, renders necessary the shelter of dwellings. From a sanitary point of view they must be looked upon as necessary evils attending civilization, life in the open air being more conducive to bodily health than residence in the most carefully constructed houses; and our efforts are directed towards reducing to a minimum their disadvantages. For this purpose five points especially require attention, viz., *dryness*, *ventilation*, *cleanliness*, *removal of sewage* and means of moderating *temperature*.

543. To secure DRYNESS of a building **soil** and materials require attention. We have seen that vegetable matter in a soil is apt to generate malaria when moisture is present; that other miasms arise from damp "made ground" containing decomposing animal matter; and that a wet soil, without organic impurities, is in itself unwholesome. The driest available natural soil, therefore, should be selected for a site, measures should be taken to remove from it any water it may contain and to prevent moisture which cannot wholly be removed from rising into floor and walls. Accordingly a position on a gentle slope is desirable; no ground should rise abruptly behind the site; all vegetable matters, as roots &c., should be removed from the selected spot.

544. Deep and thorough subsoil **drainage** is necessary in all cases where the soil is not perfectly dry; and surface drainage should carry off the rain falling on the building and near it. The former should, if possible, be constructed in ordinary cases from 4 to 10 feet below the foundations: provided with a good fall, if the ground admits, otherwise discharging into a well from which the water is raised as it accumulates. Surface drains, paved or asphalted, should be made all round the building to receive the rain falling from the roof, and should communicate with other drains or with sewers carrying off the water to a distance.

545. Such measures as have been described are, of course, only applicable to permanent buildings—barracks, jails, dwelling-houses, large or small. For temporary habitations, as **huts** or **tents**, the best sites available having been chosen, more can rarely be done than to attend to surface water, cutting trenches round them outside, communicating with a good system of surface drains. The floor should not be excavated nor earth heaped against the walls outside, but rather raised, if possible, by a layer of stones or dry gravel. The straw or other material on which the inmates lie should be dry, green boughs or herbage never being used; and it is desirable that water-proof sheeting should be interposed between the dry bedding and the ground.

546. When a site cannot be thoroughly drained, or as an additional precaution even when it can, means may be adopted to prevent **damp rising** from the soil into the floor and walls. When it is necessary to build on a saturated soil, a pavement set in hydraulic mortar or a mass of concrete should underlie the foundations of the entire building. The walls should be imbedded in concrete up to the level of the ground, or should include a course of some material impervious to water, such as slate, asphalte or overburnt bricks. A double course of slate in cement, inserted where the walls rise above the surface of the ground, will generally answer the purpose: but the best precaution is a $1\frac{1}{2}$ inch course of vitrified tile, perforated horizontally and inserted below the flooring of the lowest storey. When the soil is merely irremediably damp, the latter precaution should be taken and the whole building should be well raised above the ground level, either on a solid basement or on arches. If the former expedient be chosen, the material of which the basement is made must be carefully selected, so as to contain no substance absorbent of moisture and no organic matter. Arches are costly and on that account suitable only to barracks or large hospitals. If the soil is not malarious, the height of 3 or 4 feet thus gained will be sufficient; if it is, 8 to 10 feet will not be too much. They should be open to free perflation, but barred to exclude cattle and prevent the space below the building from becoming a receptacle for rubbish or filth. Walls are kept dry by the means already mentioned and by external coating with good, impervious cement.

547. As to choosing **materials** with regard to dryness, the least absorbent of water will be the best; and comparative estimates of the capacities of different substances, as bricks or stones of various kinds, may be roughly made by observing the quantities of water taken up by known bulks after a certain number of hours' immersion. Sun-dried or imperfectly burned bricks are very porous and absorbent; and, if used for building, should be faced externally with bricks thoroughly burnt, and internally with hard impervious cement, such as Madras chunam. Sand containing deliquescent substances, as sea-sand does, should not be used for mortar. In all cases roofs should be most carefully constructed of the best materials for the exclusion of rain from the walls on which they rest. The surface beneath the lowest flooring should be impervious to air so as to prevent the in-draught of ground-air from below.

548. Dryness of site and buildings is quite as essential in **stables** and **kennels** as in human dwellings, horses and dogs being nearly as susceptible of rheumatic and pulmonary complaints as men.

549. The air of dwellings is being continually contaminated by the pulmonary and cutaneous exhalations of the inmates and not unfrequently by impurities due to insufficient supply of water or neglect of its use. Sewage water and excreta may be allowed to remain in the building or its vicinity until putrefaction begins and contributes its products to the impurity of the atmosphere. Hence the necessity for thorough VENTILATION, which nothing can surpersede, both of individual buildings and of such groups as barracks, jails, large hospitals &c. When the sanitary condition of the inhabitants of a dwelling of any kind is unsatisfactory, impure air is more likely to be the source of the mischief than bad water or improper food.

550. The application of the principles laid down in Chapter II to the ventilation of ordinary **dwelling-houses** needs no special consideration here. It is only necessary to say that each occupied room should have direct communication with the open air, and should be independent of other occupied rooms for its air-supply; its apertures being so placed and capable of such control as to ensure abundance of uncontaminated air without draught. For these purposes the plan, so common in this country, of having an open space in the middle of the house is well

adapted, although unfortunately its advantages are rarely secured by piercing the walls of the surrounding chambers with sufficient ventilatory openings.

551. Groups of buildings, as **barracks, jails, asylums** and such like, should have their individual blocks so separated and so arranged as to ensure thorough perflation of the interspaces and free access of pure air to every side of each. They should, therefore, consist of detached buildings of sufficient size to accommodate 25 persons each (if of one storey, or 50 if they have an upper floor), as widely apart as the nature of the ground and reasonable convenience of administration permit, the intervals being in no case less than the height of the blocks. Their length should run north and south, so that both sides should daily receive the sun's rays. They should be arranged in echelon, so that no one should shelter another from the wind or from the sun's rays, and a V-plan, with either extremity turned towards the prevailing wind and the administrative offices placed within the broader end, will be found an excellent arrangement.

552. As regards internal ventilation of these blocks, the first point is to avoid **crowding**. The fewer persons occupying one barrack-room or jail-ward the better, and 25 may be taken as a convenient maximum for a single-storey building. In tropical climates each European inmate should have not less than 72 superficial feet, and more if possible, with 1,000 to 1,500 cubic feet of air-space. Beds, in not more than two rows, should be 4 feet apart, and the height of the room should be between 17 and 24 feet. In colder climates (as in hill-stations) and for Natives these numbers admit of reduction. Six hundred cubic feet and 42 superficial may taken as minima, and rooms ought not to be less han 12 feet in height. In all cases it is desirable that sleeping-rooms should be occupied only during the night, being left open and empty for thorough airing during working hours. Day-rooms should be provided for soldiers; prisoners should work in the open air or in sheds. When the buildings are two-storeyed the ground floor may with great advantage be used for these purposes, the upper for occupation during the night.

553. Free perflation is the best **means of ventilating** such rooms as these; and, accordingly, doors and windows should be numerous and on both sides. To this there is

but one rare exception, viz., when a malarious wind blows against one side of the block, in which case no opening should be made on that side. As before laid down, there should be but two rows of beds arranged at right angles to the length of the room, with their heads to the wall, two between each pair of doors or windows. These openings may be either directly opposed to each other, or (as is probably preferable) each may be opposite to the wall space between two at the other side, and six such apertures at least are necessary at each side of a room occupied by 25 men. A row of smaller windows above the main openings, with swinging sashes, is useful. In all cases rooms with windows at one side only, or opening off both sides of a corridor, are objectionable and every apartment, lobby or staircase, should have its own separate ventilation and communication with the open air. Verandahs are necessary in these climates, but they need not exceed 10 feet in width and they should be so constructed as to interfere as little as possible with perflation, being themselves ventilated by protected openings at their highest part. Sloping roofs are more favorable to thorough ventilation than flat. Free ventilation between floor and ground should be provided for.

554. When climate and other circumstances admit of free perflation by numerous open doors and windows, it is unnecessary to provide other **inlet** openings. When they are necessary, 10 square inches should be allowed for each habitual occupant. **Outlet** openings are provided either along the ridge of the roof—the best arrangement for a one-storeyed building—or by shafts, allowing one of these for every 12 occupants. They may be built into the walls or pass up in the corners of the rooms. They are best made of wood with a smooth internal surface, rising some feet above the roof, and having the upper portion blackened in order to increase the upward current by the aid of solar heat. They are surmounted with a louvre and have an inverted louvre below, where they leave the room. Their sectional area varies with the cubical capacity of the room and also with its position. As regards the latter, a ground-floor room requires 1 square inch of shaft area for 60 cubic feet, a first-floor one for 55, a second-floor one for 50. When there are chimneys, which supply outlet-openings to the extent of about 6 square inches per man, the total outlet space will amount to 16 or 18 square

inches for each occupant. If the air is so stagnant that natural ventilation is feeble or absent, it will be necessary to have recourse to the thermantidote.

555. The aggregation of large numbers of healthy persons in buildings being unfavorable to health and requiring great and constant attention to ventilation in order to obviate its disadvantages, the collection of many sick in **hospitals** demands even greater precautions. The site should be well-drained if clayey, a gravelly soil being selected, if possible; with no steep rising ground in front or rear; and in as extensive an open space as is obtainable. In addition to the ordinary noxious emanations from human bodies, the air of hospitals is liable to pollution by morbid effluvia from sick and wounded, from excretions, dressings, poultices and bandages. Latrines and urinals must be near at hand and, if not amply ventilated, will contribute to the foulness of the atmosphere. Walls, floor furniture and bedding may absorb organic putrescent matters and yield fœtid and noxious gases or vapors to the air. To dilute these and other impurities it is absolutely necessary to supply fresh air in quantities limited only by the avoiding of excessive movement. Many diseases, moreover, require pure air for their cure. Abundant supply of good air, then, is the chief point to be considered in the arrangement and construction of hospital buildings; and the best ventilated hospitals are the healthiest or least unhealthy.

556. What has been said as to the **arrangement** of barrack buildings applies also to hospitals. They should consist of small, detached wards, so far separated as to admit of freest access of light and air, communicating by covered passages thoroughly ventilated laterally and above.

557. Each building should be so **constructed** as to secure ample space and separate ventilation for each patient. It should contain a main ward to accommodate at most 30 patients and one or more smaller rooms adapted to one or two, each patient having from 100 to 120 feet superficial and 1,500 to 2,000 cubic. If the building is two-storeyed, the sick should be placed on the upper floor only. Furniture should be as scanty as possible, and of iron, (as occupying least space), so far as practicable. Ventilation should be natural, by numerous opposite doors and windows giving horizontal movement of air and by

inlets and outlets to give vertical currents, all being so arranged that no air should pass from one patient to another. To secure perflation the width of the ward should not exceed 24 feet. The beds should be placed along the walls, in two rows only, two between each pair of windows. Every room, staircase, water-closet, latrine or urinal should have its own sufficient system of independent ventilation, especial care being taken to prevent air from passing into the wards from latrines &c. Separate wards should be provided for infectious diseases.

558. When soldiers, coolies, prisoners or others are housed in **huts**, ventilation is easily provided for. Mats of any kinds, bamboos set close together or leaves of palms or other trees admit of free perflation; and huts constructed of these materials, provided they are water-tight and the inmates are suitably clothed, will be found healthy. When boards are used and are abundant, the huts should be floored, admitting air beneath; and the walls double with a space between, a plank being omitted above on the outer side, below within. If the walls are single a plank set obliquely, above the heads of the inmates, will admit air, which may also be permitted to enter beneath the lowest plank of the wall. The roof should be provided with ridge ventilators.

559. When **tents** are used as dwellings, the necessity for reducing, as low as possible, the weight to be transported causes them to be crowded to a dangerous degree.* The fact that they are but slightly pervious to air, especially if wet, increases the difficulty. They should be pitched as widely apart as possible,† occupied no longer than is absolutely necessary, and the walls raised in the day-time to windward and at night at least to leeward. The ventilation of tents admits of considerable improvement.

560. Ventilation of buildings occupied by **cattle** is too often neglected both in this country and elsewhere. The confinement of milch cows in close, unventilated quarters

* The Madras tent for 25 European soldiers covers an area of 21 × 15 feet, giving 12 feet to each. A sepoy tent is 33 × 16 × 8·5 in cubic capacity with an area of 240 to 256 feet.

† An Indian camp for *ten* companies extended 210 paces in front and 360 in depth; for six troops of cavalry the numbers were 360 and 400, and for artillery 110 and 300.

does not appear to interfere with the production of milk or to affect its nutritive qualities, but it is certain that animals so housed deteriorate in health. The practice, universal in this country, of housing cattle in the dwelling enclosures, even in large towns, is most objectionable. Places where cows or bullocks, sheep or horses* are kept should have ample floor and cubical space, and careful provision for renewal of air by ventilation. It will be sufficient to give the dimensions which are laid down for horses.

561. In **stables** not less than 100 superficial feet and 1,600 cubic should be allotted to each horse. Closed buildings are unsuited to hot climates where shelter from excessive rain and from the direct action of the sun's rays, such as trees afford, is often quite sufficient for health. A shed, either double with stalls at each side of a central wall or (as is preferable) single with front walls 12 feet in height from ground to eave, central or back wall $8\frac{1}{2}$ feet higher, and 16 feet in depth, will supply approximately the space required. The stalls should be 6 feet in width, each having its own entrance in the front wall, and, if the shed be single, apertures for ventilation in the back wall. The roof should be provided with ridge-ventilation and there should be a space between eaves and wall. The entrance-front is turned towards the sea-breeze, if there be any, or to the prevailing wind unless it be a malarious land-wind. A verandah from 6 to 10 feet in depth and 6 feet in least height may run along the whole front with advantage.

562. Without CLEANLINESS in dwellings purity of the air is impossible. Walls and floor must be kept scrupulously clean, soiled clothes put away in unoccupied rooms and washed as soon as possible, water used for ablution removed from the house without delay and excreta disposed of at once. An ample supply of water, freely used, is essential.

563. In **barracks, jails** &c., where many persons are collected together, cleanliness is all-important. Barrack-rooms should be floored with such material as to admit of being washed once a week (as little water as possible

* Poultry are often kept in houses so small that health is impossible.

being used) and dry-scrubbed on the other days. For this purpose hard stone or tiles, closely set with good cement, good timber planking, closely fitting, or asphalte are the best. The walls internally should be lined with hard cement which can be frequently washed with soap and water; or, failing this, white-wash, made from thoroughly burnt lime, should be periodically applied, dirty places having first been carefully scraped. Ceilings are to be similarly treated. In Native jails the floor must be often *leeped* and the walls whitewashed.

564. Provision for **ablution** should include a swimming-bath if possible. Shower-baths are useful in barracks. Each barrack-room should have an ablution-room at one end with shower-baths, if water in sufficient quantity can be supplied; but always ample provision for minor ablutions, one basin for four men being the usual allowance. In Native jails the prisoners should have opportunities for partial washing provided within the walls, being allowed, once a week at least, access to a tank or river for complete ablution. In our Central Jails bathing-cisterns and platforms are provided.

565. In consequence of the rapidity with which **urine** evaporates and decomposes, especially in hot climates, care must be taken for its removal from dwellings with as little delay as possible. In barracks earthenware urinals should be provided for each room in a separate chamber, with water continually running through them, or supplied with dry earth. For night-use jars of glazed earthenware are best adapted, or wooden tubs charred inside, to be emptied every morning and kept filled with water during the day. With reference to solid excreta it is only necessary to remark at present that their immediate or rapid removal from dwellings is even more essential to cleanliness and health than that of the urine; and that the latrines or water-closets should, if allowed to be within the dwelling, be kept scrupulously clean and thoroughly ventilated, and so placed that no air can pass from them into other apartments.

566. In **hospitals** all precautions necessary to ensure cleanliness must be redoubled. Walls should be coated with hard, impervious cement or glazed tiles, and frequently washed with soap and water; ceilings whitewashed once in three months if possible. Floors should be constructed

of some material such that it shall be impossible for liquids of any kind to penetrate and lodge beneath; and a well-set stone or tiled floor covered with oil-cloth will best, perhaps, fulfil this condition here. Wards should be vacated periodically in rotation, to allow walls, floor and ceiling to be thoroughly cleansed. Beds and other furniture, as far as possible, should be of iron, not only to save space, but also because this material is inabsorbent of organic fluids and capable of being more completely cleaned than wood. Coir or horse-hair is better for bedding than cotton, as being less absorbent; and than straw, as being less bulky. Blankets and other bed-clothes should be light in color, so that dirt may be at once apparent, and should be frequently changed. Nothing which can give off effluvia must be permitted to remain in a ward or its neighbourhood a moment longer than can be avoided, especial attention being paid to the removal of excreta. Urinals, latrines or water-closets must be kept perfectly clean, abundantly supplied with water or dry earth, and continually visited by the attendants, the dry-earth system being unquestionably the best adapted to Indian hospitals. Wards occupied by specially offensive cases, such as cases of small-pox, compound fracture or foul ulcers, should be supplied with deodorants; and dressings, poultices &c. should be sprinkled with them before removal. The dead should be immediately removed from the wards.

567. Both the inside and outside of **huts** should be whitewashed, and the application of lime renewed after scraping, whenever the surfaces begin to appear discolored. The floors, if of planks, should be periodically taken up, and the space underneath cleaned out. Earthen or gravel floors should be scraped and fresh material substituted for the removed surface.

568. **Tents** should be frequently moved to fresh ground, three days being the longest time that it is desirable that they should occupy the same position. If circumstances render a change of site impossible, the surface should be scraped off and fresh dry earth or gravel substituted. Fresh straw should be supplied as often as possible, if this be used for sleeping on, the soiled beds being removed and burnt. When a camp is standing for a long time it would be well to vacate tents periodically, for cleaning and airing, as in the case of hospital wards.

569. SEWAGE includes the water which has been used for washing and cooking, the refuse of trades and manufactures, the liquid and the solid excreta of the inhabitants of dwellings and of their domestic animals.* These should be removed as rapidly as possible and so disposed of as to be productive of neither danger nor inconvenience to any one.†

570. So far as the **private houses** of Europeans and of the wealthier class of Natives in this country are concerned, the system adopted for the removal of sewage requires only attention to a few details to be sufficiently satisfactory. The water from the bath-rooms and dressing-rooms should be led away from the house by drains and not allowed to sink into the ground close by. Water from cook-rooms requires still more care for its removal and the drain which carries it away should be frequently flushed. Excreta, solid or liquid, should be immediately removed, if the not altogether commendable practice of using bath-rooms as latrines be permitted. It is certainly preferable to have a latrine of some kind separate from a house, connected with it, if necessary, by a covered passage. In either case a deodorant should be applied to fæces—wood-ashes, dry earth, carbolic acid or McDougall's powder. If daily removal from the premises is impracticable, excreta may be allowed to accumulate, (as far as possible from dwellings), provided they be fully deodorized, until they can be utilized for the garden or carted away to the common receptacle of town refuse. Cess-pools in compounds, or pits not periodically and frequently cleared, are absolutely inadmissible.‡ In the houses of the poorer

* Average (European) sewage is estimated to include 72 parts per 100,000 of solid matter in solution, and 45 parts suspended.

† The following are convenient deodorants of sewage:—1 gallon of saturated solution of perchloride of iron to 15,000 gallons of sewage; 1 lb. sulphate of iron in 8 gallons of water to 1,000 gallons; 3 gallons dilute carbolic acid to 1,000 gallons.

‡ In certain circumstances the use of cess-pits may be an unavoidable evil. They should then be carefully constructed as far as possible from dwellings, and frequently emptied. They should be square in horizontal section, lined with cement and backed with puddle clay. A partition should divide into two receptacles; one for liquid matters, which should be pumped up for irrigation. They must be covered in, and provided with ventilating pipes containing trays of charcoal frequently changed. Every precaution must be taken to prevent the possibility of drinking-water being contaminated by them.

Natives, the habits of the people, especially in the country, prevent the accumulation of excreta; except, unfortunately, in case of illness. The ashes of wood or of bratties are freely applied, however, and disease can rarely be traced to this cause. Provision for the removal of foul water from such houses is generally very inadequate, it being in most cases allowed to trickle out of the cook-room &c. and stagnate where it issues. Efficient house and street drainage and abundant water-supply are the obvious remedies for this state of things.

571. The removal of sewage and its ultimate management become much more serious and difficult questions when **many persons** are collected together in towns or cities; and even in relation to barracks, prisons or other large buildings. In these cases sewers have to be provided, requiring careful adaptation to the circumstances of the locality and the work they have to do. How to dispose of the sewage which they remove from the buildings has also to be considered, a problem which does not admit of any general solution, its conditions varying so widely in various places.

572. Some of the items which make up the **quantity** of sewage admit of estimation. The urine may be calculated at an average of 40 fluid ounces daily for each man, woman and child; or 25 gallons for a population of 100 persons of all ages and both sexes. The solid excreta of an adult European weigh on an average 4 ounces and the average for a mixed European population may be taken at 2½ ounces.* The corresponding quantities for Natives will be 12 and 7½ ounces. While the urine may be removed by sewers without any but economic objections, it is eminently undesirable to admit the fæces to them and other methods of removal must, if possible, be adopted. The refuse water which makes up the greatest part of sewage cannot be calculated beforehand, depending as it does on the water-supply and other considerations.

573. The object of sewers being the removal of refuse matter from dwellings quickly and safely, we have to **guard against** obstruction, against the escape of foul or

* Letheby gives the average of urinary secretion of a mixed population as 31·851 daily, and of solid excreta as 2·784 : 2,266 lbs. of the former and 177·5 lbs. of the latter, daily, for 1,000 persons.

noxious gases into houses or their vicinity and against the contamination of the water-supply by leakage of liquids and gases into the soil. The *materials*, *construction*, *ventilation* and *cleansing* of sewers have to be considered, with a view to obviating the disadvantages to which they are liable, defective sewerage being worse than none. The division into house-drains and street-drains is convenient.

574. The best **materials** for the former are pipes of glazed earthenware, their size regulated by the amount of refuse to be discharged, but never falling below 4 inches diameter. This size will be sufficient for a water-closet or a sink and will communicate with a pipe of 6 inches. A pipe of 9 to 12 inches diameter will be sufficiently large to carry off the house-refuse of 1,000 persons. Street-drains may be of the same material up to a diameter of 24 inches; but for any size above 12 inches well-burnt bricks set in hydraulic mortar will be best.

575. As regards the **construction** of house-drains, the chief points are sufficient fall and accessibility for cleaning or repairs. If the discharge of water be very copious, fall may be dispensed with but, in general, an equable gradient of 1 in 48, or $\frac{3}{4}$ inch in a yard, is desirable. The pipes should not run beneath floors or be built up in walls; and, where the latter are pierced for the passage of drains, the openings should be large enough to allow easy removal in case of breakage. Street-drains should be oval in vertical section, the smaller end downwards, none being of a smaller size than 6 inches diameter and all of such dimensions as to carry off the ordinary amount of sewage without being more than two-thirds full. They should be made of materials impervious to water, as brick in cement. The ground on which they rest must be hard and firm, subsidence of any part leading to fracture and leakage or to obstruction from solid matters being arrested in the hollow. Sudden differences of level are objectionable; if any exist, free access at the spot should be provided by a man-hole to prevent accumulation of solid refuse. The fall should be equable, varying in degree inversely as the size of the sewer and the quantity of water passing through it; abundant flushing compensating deficiency of fall, though the latter should always be provided if practicable. From 1 in 250 to 1 in 750 should be allowed, a slight gradient being sufficient when the water-supply is moder-

ately abundant. The velocity of the stream should not be less than 2 feet per second, nor more than 4½. There should be no junctions at right angles, either with house-drains or other street-drains. Changes of direction must be made by curves of long radius; never, in main sewers, less than ten times the horizontal diameter of the section of the drain. Friction should be reduced to the lowest, both by making internal surfaces as smooth as possible and by restricting the size of the sewer to actual requirements, the same quantity of fluid being more retarded by friction in a wide than in a narrow drain. The mouth of a main sewer should be protected against the entrance of the rising tide, if it open into the sea, forcing back its contents, and from the action of wind blowing directly up.

576. The **velocity of discharge** from sewers is given by the equation $V = 55\, a \sqrt{2 f d}$: where V is the velocity in cubic feet per minute; a the sectional area of the sewer; f the number of feet of fall per mile; d the hydraulic mean depth, *i.e.*, one-fourth the diameter if the sewer is running full, or a divided by the number of feet of circumference occupied by the stream, if the latter does not fill the sewer.

577. The relation of **gradient** to diameter of sewer and velocity of sewage-flow is given in the following Table* :—

Diameter in inches.	Velocity in feet per minute.	Gradient required.	Diameter in inches.	Velocity in feet per minute.	Gradient required.
4	240	1 in 36	18	180	1 in 294
6	220	1 ,, 65	21	180	1 ,, 343
8	220	1 ,, 87	24	180	1 ,, 392
9	220	1 ,, 98	30	180	1 ,, 490
10	210	1 ,, 119	36	180	1 ,, 588
15	180	1 ,, 244	48	180	1 ,, 784

578. Within the dwelling, at the junction of the house-drain with the street-sewer and along the whole course of the latter, careful provision must be made for **ventilation.** Good materials and skilful construction will fail to prevent the escape of foul gases into houses unless means be taken for their discharge in places where they will be rendered innocuous by dilution. If water-closets are used, a venti-

* Quoted by Professor Parkes from Mr. Wicksteed.

lating pipe should rise from the drain close to the closet, terminating above the top of the building. House-drains should not directly join the street-drains into which they discharge; the corresponding mouths being connected by one of the many forms of trap, open to the air, permitting liquids to pass, but opposing a stratum of water not less than $\frac{3}{4}$ inch in depth to the passage of gas from street-sewer to house-drains.* If, however, there be strong gaseous pressure in a drain, the gas may pass through water in a trap and get into a building thus protected. The junction should be as far as possible from the house; and a ventilating shaft or pipe, rising from the street-side of the trap and carrying up the gases issuing from the sewer, will be useful. Main drains should have ventilatory openings with lofty shafts every 100 yards. Trays containing charcoal broken into small pieces may be placed with advantage at all openings, care being taken that the layers of charcoal be not so thick as to impede the passage of the gases through them.

579. Sewers of every kind must be kept free from obstruction by regular **cleansing**, for which flushing is the best means and one which should be used at least once a day if possible. In houses with an ample supply of water there is no difficulty in arranging for a copious discharge through the drains at one time daily. Water-closets and sinks may have boxes beneath them to receive the water &c., so suspended on pivots as to turn over and empty their contents into the drain-pipe only when completely filled. Street-drains also must be periodically flushed unless the fall and abundant water-supply render the operation unnecessary. They should receive the rainfall except in those rare cases in which this is so copious within short periods as to make provision for its discharge by the sewers inordinately expensive. They should be large enough to admit of the passage of a man through them, and facilities for frequent periodical inspections should be afforded by man-holes, in the side if possible, which should be closed, when not in use, with air-tight iron doors. It often happens that matters collect on the walls and roof of

* A convenient trap consists of an iron box divided by a vertical partition not reaching to the bottom and holding water to at least $\frac{3}{4}$ inch above lower margin of partition. The house-drain discharges into one division of the box, the other into the street-drain.

sewers, which resist flushing and require other measures for their detachment.*

580. The removal of sewage from dwellings and their neighbourhood, with as little delay as possible, being effected by sewers or otherwise, a question of great and growing importance has to be answered, viz. How is the refuse of cities, towns and large institutions to be **disposed of?** In the case of thin country-populations there is no difficulty; the soil receives and deodorizes excreta &c., and plants utilize them. When larger collections of people are concerned the problem becomes one of considerable difficulty, two sanitary axioms being premised, viz., that sewage must not be allowed to remain and accumulate near dwellings, and that it must not be buried in pits. The utilization of sewage after removal is, for our purpose, a matter of secondary consideration, though it will be found that the best method of disposing of sewage is to apply it to the fertilization of land.† Two other plans may be briefly considered before describing the principal proposals for carrying out this object. Sewage may be discharged into the sea, or into a river.

581. Discharge into the **sea** is sometimes a convenient means of disposing of sewage: and it is one which, with a few simple precautions, is seldom objectionable, except from the economic point of view, highly valuable fertilizing material being wasted. The outlet of the pipe leading from the sewer should be submerged at low water. Its mouth should be provided with a tide-flap, opening outwards, to exclude, as far as possible, the sea-water. When the mouth is uncovered, it should open so as to prevent the wind blowing up the sewer and forcing back the gases. As this result cannot always be prevented, it is well to place a lofty ventilating shaft upon the sewer at its junction with the outlet-pipe.

582. Discharge into a **river** is permissible only when the water is not used for domestic purposes in any part of

* The sanitary statistics of towns which have recently been provided with efficient sewerage show a remarkable decline in the total death-rate as well as in the number of deaths due to enteric fever.

† The manurial value of the urine excreted in 24 hours bears to that of the fæces the ratio of 6 : 1.

its subsequent course before complete removal of putrescible matters has taken place by subsidence, by the growth of water-plants and by oxidation ; or when the volume of water bears so very large a proportion to the sewage as to render the latter harmless by dilution. It is impossible to lay down beforehand when either of these conditions is fulfilled in any particular case ; purity of the water on careful examination is the only test. In India it rarely happens that this method of disposing of sewage is practicable with due regard to health, on account of the shrinking or drying up of rivers during the hot season.

583. Both the methods mentioned above are open to the the serious objection that they involve the waste of invaluable fertilizing material ; and **combustion** of the more solid refuse is little less wasteful, though more effective and more safe. Cinerators should be erected for this purpose, as far from habitations as possible ; and the resulting ashes can be used as a deodorant and as a manure. In this country cultivators will buy ashes for manure, but not dry rubbish ; so that, on the whole, combustion is one of the best means of getting rid of dry refuse.

584. Many **other plans** have been suggested and employed which combine the removal of sewage with its utilization by application to the land. The most important of these may be briefly considered under the heads of treatment by *subsidence*, by *precipitation*, by *filtration*, by *irrigation*, by *trenching* and by *dry methods*.

585. Treatment by **subsidence** is suitable only for small quantities of sewage, as the product of a house, a barrack or jail or, at most, a village. The sewer discharges into a tank, or into trenches four or five feet deep and eighteen inches wide at bottom, with outlet or outlets at top. The more solid parts subside, are periodically removed and, being mixed with other solid refuse or with earth, are applied as manure. The effluent water, still containing all dissolved and much of the suspended impurities of the sewage, is to be used for irrigation only, being altogether unfit for admission into streams or rivers.

586. The latter remark is applicable to the water which flows off after **precipitation** processes also. In these the sewage is received into large tanks and certain substances are then added to it which promote the separation and

subsidence of a large proportion of the solids suspended or dissolved, the subsided mud being used as manure. Lime is a good precipitant but impairs the fertilizing property of the result by removing ammonia. Aluminous substances are more suitable; and the A B C process, which employs a mixture of alum, blood, clay and charcoal, appears to have been somewhat successful, financially. Charcoal of various kinds has been recommended, as well as other substances which it is needless to enumerate.

587. **Filtration** requires a large extent of surface, a permeable soil and deep subsoil drainage with suitable discharge. The ground should be divided into four parts, so that the sewage should flow over each for six hours. A loose marl containing alumina and oxide of iron is the soil best adapted to this process, but sand answers well. The drains should be at least six feet from the surface, when, allowing one cubic yard for 8 gallons of sewage, one acre (giving 9,680 cubic yards) would filter 77,500 gallons in 24 hours. In some cases an acre has taken 100,000 gallons. The land should be cropped to remove the intercepted solids, which include all suspended and some dissolved matters, ammoniacal salts among the latter. Nitrogenous organic matter is either retained in the soil or oxidized if the sewage is not excessive in proportion to the land. The water draining off after such filtration, carefully conducted, is apparently good and may be discharged into large streams and used for some domestic purposes; but it should not be drunk.*

588. Sewage **irrigation** yields on the whole more satisfactory results than any other of the wet methods and is more generally applicable. It requires an extent of surface (varying, of course, with the degree of looseness of the soil) which may be roughly estimated as one acre for every 100 persons in the community and about 70 yards square will receive 2,000 gallons of sewage in 24 hours. Large crops of grasses, cereals, roots and culinary vegetables can be raised, year after year, from land thus irrigated.†

* The standard purity of water effluent after filtration or irrigation, as fixed by the Thames Conservancy Commissioners is, in grains per gallon:—Total solids, 70; suspended, 3; organic carbon, 2; organic nitrogen, 0·75.

† In India the most paying crop yet tried is *hurryali* grass.

The sewage should be brought to the land as rapidly as possible and putrefaction may be advantageously delayed or prevented by the addition of small quantities of carbolic acid. The liquid trickles down a prepared slope, over the ground to be irrigated, at the rate of 8 feet per hour, saturation of the soil being guarded against by deep draining unless where it is so sandy* or otherwise permeable as to render the precaution unnecessary. Irrigation should be intermittent, to ensure aëration of the soil. The effluvia are rarely such as to constitute a nuisance, but it is desirable to choose ground distant from houses. Enteric fever, dysentery and the prevalence of entozoa have been predicted as probable consequences of sewage irrigation, but there is no evidence of the occurrence of such results, nor need they be apprehended if reasonable care be used. In some places the practice has been pursued for years without any bad effect. The water is not freed from impurity by irrigation to the same extent as by filtration; but it loses its suspended matters and some of its dissolved organic impurities, if not allowed to run too quickly off the land. The financial results of this method are more satisfactory when rain and surface water are excluded from the sewage.

589. The system of **trenching** is well adapted to jails, where labor is abundant. The solid and liquid excreta, with or without admixture of dry earth or other substance, are collected daily and buried in trenches, from a foot to foot and a half in depth, which are filled in with earth. After two or three months, the ground is ploughed over and cropped. When two or three crops have been taken the process may be repeated. Where there are soldiers' gardens this plan may be applied to barracks with great advantage.

590. The **dry methods** consist in mixing some deodorant with the excreta, excluding water as far as can be done, and removing the solid mixture for application to the land. It is desirable to keep the solid and liquid excreta separate if possible, putrefaction being thus retarded. When water is deficient, or when, though there is abundance of water, there is no fall for sewers, it will be necessary to remove excreta at regular intervals by some

*Sandy soils yield the best results.

means of this kind. Where labour is abundant, as in jails, or where expense is unimportant in comparison with perfect cleanliness, as in barracks and hospitals, dry methods must be adopted. The ashes of wood or bratties, charcoal, McDougall's powder or dry earth may be added to the excreta; ashes being the cheapest and most effective for fæcal matters, but not for urine on account of the liberation of ammonia when alkaline bases are present. In some of our municipal towns ashes from the combustion of dry rubbish is superseding dry earth, the cost of production and removal being considerably reduced.

591. The best kind of **dry earth** for this purpose is that containing vegetable matter. Applied to sewage, solid or liquid, it deodorizes it at once. Intimately mixed with the excreta by means of a kind of mill and kept stored in a shed, protected from water, it may be used four or five times in succession before removal for use as manure, in which condition it is called *poudrette*. It should be added immediately to the fæces; the urine, if it can be kept separate, should, after receiving a small quantity of carbolic acid, run into a box filled with dry earth. Frequent periodical removal is essential to the efficient working of the system. Three pounds daily will be required for each European and five pounds at least for each Native. The large amount of labour required and the difficulty of keeping the earth dry in the rainy season are objections to the use of dry earth; but, in the cases of jails, hospitals, barracks, schools &c., are far outweighed by the benefits. The impossibility of maintaining the requisite supply of earth must always prevent the application of the method to large towns.

592. We have now to consider the means of adapting our dwellings to climate, that is, of moderating TEMPERATURE as may be most conducive to health and comfort. Houses may need to be either *cooled* or *warmed*, the latter being rarely necessary in the stations with which we have to deal.

593. In tropical climates the **coolness** of dwellings depends to a considerable extent on their original construction and materials; at least attention to these will make houses less hot. For positive cooling the evapor-

ation of water is almost the only means at our disposal, with the aid of artificial ventilation if the air is stagnant.

594. Houses should be built of the **material** least absorbent of heat which can be obtained. Thick walls of brick absorb much heat during the day, giving it out again at night. Walls should be white externally or of some light shade of color less trying to the eyes. Thatch is a good material for the roof but shelters rats, snakes &c. and is exposed to the risk of incendiary or accidental fires. A layer of thatch under tiles conduces to coolness.

595. Much may be done by careful **construction** to exclude excessive external heat from dwellings. Double walls with openings into the interspace above and below, so as to allow free circulation of air, will be found effective. Verandahs should shelter, as far as possible, the main walls from the direct action of the sun. The upper portion of the walls of barrack-rooms, school-rooms and the like may be open work of brick or tiles, protected from sun and rain. Roofs, if terraced, should be double with free admission of air between. In places where the days are hot but the nights comparatively cool, glazed doors and windows should be provided, which can be closed at sunrise and retain the cool night air for several hours. A double door helps to exclude the heated external air. This plan is only applicable to houses spacious in proportion to the number of their inhabitants. Applied to schools &c., it is liable to abuse and neglect of efficient ventilation.

596. Cooling by **evaporation** requires that the air shall be dry, (to absorb the watery vapor), and in movement, to bring fresh volumes of air into contact with the evaporating surface. Sprinkling water on floors is useful in some degree. A hot, dry wind blowing through a mat of kuskus or of ordinary grass cools the internal atmosphere considerably. If there be no movement of the air, the punkah or the thermantidote must be employed. Wet cloths or tatties or melting ice may be placed in the mouth of the latter and a wetted fringe of kuskus attached to the former. None of these methods will avail if the moisture of the air* exceeds 70 per cent. of saturation.

* The latent heat of water in vapor is 966°·66 F.; or, in other words, 10 lbs. (a gallon) of water in evaporating absorbs from surrounding substances as much heat as would raise 9,667 lbs. of water 1° F. The evaporation, therefore, of one gallon will (theoretically) cool 9,667

597. In colder climates buildings require to be **warmed** artificially, though, except for aged persons, infants and some sick, it is a matter rather of comfort than of health. Healthy adults, provided with sufficient food and clothing, will generate and retain heat enough for the needs of the system in any climate. The old suffer from cold, and a severe winter in temperate climates proves fatal to many; a lower temperature than 60° F., therefore, should be avoided. The thermometer should not be allowed to fall below 70° in rooms where new-born infants lie. As to the sick, hospital-wards should vary in temperature according to the nature of the diseases which they receive. Acute febrile diseases with great heat of skin are benefited by a low temperature and the slow passage of cool air over the surface. Convalescents from such affections, however, bear cold ill, and wards intended for them should not be colder than 60° F. Surgical wards rarely require artificial warming if the quantity of bed-clothing be carefully regulated. In all cases where artificial warming is carried on, care must be taken to avoid the production of draughts of cold air; so that when large buildings are artificially heated the lobbies and corridors should be warmed as well as the rooms; else cold air will enter the latter when the doors are opened.

598. Warming by **radiation** which communicates heat through, but not to, the air, is the best for health. It is done by the open *grate*, the *stove*, *hot-water*, or *hot-air*, or *steam* pipes. **Another means** is the introduction of *hot-air* directly into the room or building.

599. The use of the open **grate** is costly and wasteful; and as the heat emitted diminishes as the square of the distance from the radiant surface, this method is unsuited to large rooms. It has the advantage of aiding ventilation by supplying an outlet opening and a powerful draught. If preferred, as it often is, on account of its greater cheerfulness and through force of habit, the fireplace should be so

---

lbs. of water 1° F., or 483·35, 20° F. The specific heat of air is 0·2375, that of water being 1; therefore what would cool 483·35 lbs. of water 20° F. would cool (483·35÷0·2375=) 2,035 lbs. of air; or 26,455 c.f. at standard temperature and pressure at which about 13 cubic feet weigh 1 lb. At 80° F. the number of cubic feet of air cooled 20° F., by complete evaporation of one gallon of water, may be taken at 27,500.

constructed as to economize fuel and secure to the utmost radiation of the heat. The grate and fireplace invented by Count Rumford fulfil these conditions. In these the width of the grate at the back is one-third of the depth of the hearth-recess, the sides of the latter sloping outwards. The depth of the grate from before backwards is equal to the width at back. Sides and back of the recess should be built of non-conducting material. The opening into the chimney is narrow and capable of modification in size, for management of draught and rate of combustion. The grate should be set as far forward as possible, but directly under the chimney-throat, so that the products of combustion may be completely removed. A well-constructed grate of this kind will radiate heat into every part of a small room.

600. **Stoves** are convenient for warming huts but their use is attended with considerable disadvantage. They impart a good deal of heat to buildings inasmuch as they not only radiate but, becoming hot externally, heat the air in contact with them and act by conduction and convection as well as by radiation. In some air is heated, besides, in chambers, and poured into the room. If allowed to grow too hot the air is burnt and smells disagreeably. Not unfrequently they become red hot; and if they are made of cast iron, and if coke or anthracite be the fuel used, carbon monoxide passes freely through them into the atmosphere of the room.* This diffusion is less active if the material be wrought iron or fire-clay. When a stove is used its chimney should pass along the hut or room, below the roof or ceiling, so as to yield as much radiant heat as possible.

601. Warming by **hot water** circulating in pipes and giving out radiant heat is, on the whole, the most manageable and effective means. It secures a moderate temperature at no great cost. There are two methods of using hot water for this purpose, *low-pressure* and *high-pressure*. In the former the water is heated in a boiler to a temperature of about 200° F. and circulates through pipes, conveying it into all parts of the building to be warmed, by convection; apertures being provided at the highest

* It is said that this inconvenience may be obviated by coating the exterior surface with silicate solution.

point for the escape of air. Within the rooms &c., the pipes (which should have a polished external surface before they enter, to diminish radiation, and be blackened afterwards to increase it), are coiled, or expand into metal cases or have the radiating surface otherwise increased, according to the cubic capacity of the apartment and the temperature of the outer air. The latter being variable the extent of radiating surface required can be only approximately estimated for any particular case. It has been laid down that, with water at 200° F., the quotient of the cubic capacity of the room in feet by 200 gives the number of feet of four-inch pipe necessary to raise the temperature from 32° F. to 55° F. Thus five feet of such a pipe will warm to 55° F. 1,000 cubic feet of space. This allowance will probably be found sufficient for corridors and passages; but work-rooms will require six feet, and the rooms of dwelling-houses twice as much, for every 1,000 cubic feet. If the high-pressure plan be adopted, two-thirds of this allowance, or a little more, will be enough, the water being raised to a temperature of 300° F. to 350° F. In this method there is no boiler and the pipes (which are made of wrought iron, five inches thick) pass through a fire. There is, perhaps, less risk of explosion when this method is used.

602. Warming by **steam** is effective but more costly than the plan last considered, unless there be waste steam to be utilized. The radiating surface, one square foot of which is usually allowed for 200 cubic feet, is sometimes increased by soldering to the steam-pipe plates of copper or zinc, over which a woollen cloth can be thrown if the heat become excessive.

603. **Hot-air** methods, in which air introduced from without is heated and then brought into the room, have the advantage of promoting ventilation, but they require careful management to avoid overheating and to regulate the admission of the hot air. The latter may be heated in a chamber constructed behind and at the sides of an open grate or stove and communicating by a pipe with the outer air; or by passing over hot stones or tiles or plates of iron or of copper, or pipes containing steam or hot water.

604. The bad effects of **overheating** the air are a peculiar and disagreeable burnt smell (probably due to

the charring of organic matter) and excessive dryness of the hot air. In rooms warmed in this way a difference of more than 15° F. has been observed between the wet and dry thermometers, indicating a degree of humidity much below that necessary for health; while in places warmed by radiation the difference is never more than 8° F. In such a case the heated air should be brought into contact with water before its introduction into the room, thereby losing some of its excessive heat and acquiring moisture. The heating surface should be extensive, a large quantity of air moderately warmed being better than a smaller body highly heated. The temperature of the surface should not exceed 140° F. nor that of the air entering the room 75° F.

605. To ensure proper **admixture** of the warmed air with the atmosphere of the room, the former should enter low down, but in such a place that it shall not be breathed before mixing and that it shall not immediately escape, either by an open chimney or other outlet-aperture. There is always a possibility of the current being reversed and the warmed air blown back, especially when the weather admits of open doors or windows.*

606. A few words of caution may be added on the subject of **wall-papers**, which are coming more freely into use in India. Those of a green color frequently include arsenic, sometimes in considerable quantity; and the same mineral is occasionally present in white and cream-colored enamelled papers, and in drab which have been tinted with ochre. Recently *washable* paper-hangings have been patented, which harden after being put up and which will be most valuable for hospital-wards or private rooms in which infectious diseases may be treated.

* A rough estimate of the heating power of various fuels may be useful in connection with this subject. Taking the calorific power of good coal at 90, that of wood-charcoal will be 95; coke, 84; wood, 32; peat, 19.

CHAPTER VII.

CLOTHING.

607. The hygienic objects of CLOTHING are the prevention of sudden or rapid reductions of bodily temperature and protection against excessive solar heat, with as little restriction upon the movement of the limbs and the action of the viscera as possible. The subject, therefore, requires consideration of the ordinary *materials* used for clothes and of the *garments* themselves.

608. MATERIALS differ in powers of absorbing, radiating and conducting heat, in capacity for absorbing moisture, (this quality being of great importance because the condensation of cutaneous vaporous exhalations in the clothing is attended by the evolution, as evaporation by the abstraction, of heat) and in permeability by gases. Imperviousness to water from without, or to gases and vapors from within, is a quality possessed by some materials.

609. Amount of heat **absorbed** varies slightly with material, considerably with color. Thus, the absorptive power of white cotton being taken as 100, that of white linen may be represented by 98, of white flannel by 102, of white silk 108. If differently colored cotton shirtings be compared and white be taken as 100, pale-straw will be 102, dark yellow 140, light green 155, dark green 168, Turkey red 165, light blue 198, black 208. **Conduction** depends partly on the nature of the substance itself, partly on the degree of looseness of texture of the fabric.

610. The color or texture of a cloth has little influence upon its power of **radiation,** in which silk and cotton exceed wool. **Permeability** to air is necessary to health and comfort, and varies considerably in different materials. Thus, taking the permeability of flannel at 100, that of linen is 58, of silk 40, of buckskin 58, of chamois 51.

611. Cotton, linen, wool, leather and india-rubber fabrics are those which require notice. **Cotton,** the commonest and cheapest material for clothing, is used either alone or in combination with linen, silk or wool. It is durable,

non-absorbent, (so that perspiration passes through and, evaporating, produces chill), and slightly inferior to linen in conducting power but much superior to wool. Cotton clothing, therefore, is well adapted to hot climates, except while the body is perspiring after exertion; in which case a dry woollen inner garment is preferable. Merino and similar fabrics are cotton with 20 to 50 per cent. of wool, the two materials being open together to make the yarn.

612. In conducting power and absorbing capacity **linen** is slightly superior to cotton. The two substances and fabrics in which both are mixed may be considered equal in suitability for clothing.

613. In cold climates the low conducting power of **wool** makes it the best material for protection against cold. Its great superiority to cotton and linen in absorptive capacity renders it most suitable for under-clothing in all climates; and especially after exertion, when it condenses the cutaneous vapor and so, by causing evolution of latent heat, prevents too rapid cooling. Woollen fabrics deteriorate by washing, shrinking and becoming harder.

614. It is sometimes useful to be able to **distinguish** these three materials from each other, adulterations and admixtures being not unfrequent. For this purpose the microscope and chemical tests can be employed.

615. The **microscopical** appearance of cotton-fibre is that of a flat ribbon with thickened edges and twisted about 600 times in an inch. Linen-fibres are finer, cylindrical and slightly knotted at regular intervals. Wool-fibres are cylindrical, crossed obliquely by lines and longitudinally by fainter marks. The markings become indistinct by age and wear and the fibres separate into their constituent fibrillæ.

616. Cotton and linen, both composed principally of cellulose, have nearly the same **chemical** characters but may be distinguished by the more rapid solution of the former in ammoniacal solution of copper. They agree in being colored brown by iodine, blue by minute quantities of iodine and sulphuric acid; in being undissolved in boiling liquor potassæ of sp. gr. 1050 and in not becoming yellow in strong nitric. Wool is soluble in boiling liquor potassæ, is little affected by strong sulphuric, is colored yellow by nitric and is insoluble in solution of copper in ammonia.

617. **Shoddy** is old woollen cloth mixed with other materials and re-made. Under the microscope the foreign fibres can be recognized and the wool-fibres will show various colors as well as be irregular in figure, with markings indistinct. Shoddy yields more readily to the action of liquor potassæ than new wool.

618. **Leather** is rarely used, except in the coldest climates, for any clothing but that of the hands, feet and legs. It is impervious to rain and wind, as well as a bad conductor of heat, and is, therefore, a very warm material for dress. It retains and condenses the perspiration and is for this reason unsuitable for constant wear, (except in boots, shoes and leggings), in hot or temperate climates.

619. Water-proof fabrics, generally preparations of **india-rubber**, have the same advantages and disadvantages as leather. They are apt to soften and stretch in hot climates; but will be found useful, in coverings for the whole body and dress, in places where the rainfall is heavy.

620. The absorption of **contagions** is supposed to resemble that of odors; which varies with absorptiveness of moisture. On this color appears to have some influence; black absorbing most freely, and blue, red, green, yellow, white, in the order given. It follows that a white cotton dress is best adapted to the sick-room, a black or dark woollen garment worst.

621. The GARMENTS themselves may be divided according to the parts they cover into clothing for the *head*, the *trunk*, the *lower limbs* and the *feet*. One principle applies to all; namely, that they should be so shaped and so worn as to admit of the freest action of the muscles and to exercise the least possible pressure upon viscera and blood-vessels.

622. The **head-dress** should be light, loose, not conductive of heat, impervious to rain. It should shelter the eyes from direct sun-light by projecting in front and be so formed behind that the rain which falls upon it shall not run down between the trunk-clothing and the body. An empty space should intervene between the head and its covering, with holes for ventilation so placed as not to admit rain. Its size should be as small as is compatible with these conditions, which are fairly fulfilled by hats or helmets of felt, cork or pith, or basket-work covered with one of these materials. For native men a well-made turban is the best head-covering, the fez fulfilling not one of the conditions stated above, except that of being made of non-conducting material. Native women seem to find

sufficient protection in their hair, being less exposed than the men to sun and rain. European women clothe their heads only for what are considered to be ornamental purposes.

623. For the clothing in immediate contact with the **trunk** flannel is the best material under favorable circumstances ; but these do not often concur and disadvantages may predominate. Flannel is much more costly than cotton or linen fabrics. It deteriorates much more rapidly than they do by repeated washing, while, if unwashed, it becomes much more offensive. Fine flannel under-clothing therefore is the best when it can be frequently changed, and replaced when it becomes shrunken and hard; otherwise, merino or some other mixed fabric of wool and cotton or wool and silk should be worn ; and over this a garment of cotton or linen cloth. Coats or other outer body-clothing may be of this material, or of silk, in hot climates, of woollen fabrics in cold; never made so tight as to interfere with free action of the limbs or the muscles of respiration, or to press injuriously upon the abdominal viscera. The dress of all classes of clothed natives, (except those who, like the sepoys, have been compulsorily Europeanized, or a few others who have voluntarily sacrificed comfort and health to conformity with Europeans in costume), is, especially in the case of the women,* far more reasonable and wholesome than that of the Europeans settled amongst them. It may be added to what has been said above about the clothing of the trunk that all pressure upon the **neck** by tight collars, cravats or bands must be most carefully avoided.

624. What has been said about clothing for the trunk applies also to that of the **lower extremities.** Inner drawers of flannel, thin or thick according to climate or season, will be found as useful as flannel vests or shirts; and aid in protecting the abdominal viscera from changes of temperature, thus rendering the use of a flannel belt unnecessary.

---

* It is needless to remark how utterly regardless of the first principles of hygiene European women of the upper and middle classes are, in India and at home, in the matter of dress; how they sacrifice their own health and that of their offspring to ludicrously false ideals of grace and beauty.

625. As to the covering of the **feet**, stockings or socks of cotton or wool, or a mixture of both, should be worn inside the boots or shoes.* The former should fit closely, without folds or wrinkles but also without impeding full extension of the toes. The latter should be, as far as possible, impervious to wet, and of such shape and size as to allow of free extension of the foot in length and breadth during the action of walking, when it increases nearly one-tenth longitudinally and rather more laterally. The inner outline should be straight, never turning outward at the toes; the heel low and broad, permitting the normal action of the muscles of the calf and affording firm support to the weight of the body. The sole should be flexible, especially beneath the tarso-phalangeal joints, and several contrivances have been suggested for giving flexibility without admitting wet. Boots and shoes should be "right and left" and, if possible, made for each person after careful measurement. Sepoys should perform their ordinary duties bare-foot and be provided with sandals only for use on exceptionally rough ground. Bare feet are much more cleanly than dirty stockings or boots; and the sole becomes sufficiently hardened and thickened by use to render it secure from injury in ordinary life. European children in this country may be allowed, with comfort and advantage, to remain bare-footed, at least within doors, or to wear only thin and flexible shoes; preserving their feet as long as possible from the distortion which appears to be inevitable in after-life, especially in women.

626. The following preventives and remedy for **foot-soreness** have been recommended. The socks should be frequently washed and greased. Before starting on a march the feet may be bathed in hot water to which a little alum has been added; or dipped in hot water, wiped dry, and rubbed to a lather with soft soap before putting on the socks. An ointment consisting of 20 parts unguentum zinci with 1 part of tannin has been found a useful application by the German troops. If the feet are sore at the end of the march, they may be wiped with a wet cloth and rubbed with tallow and spirits mixed in the palm.

---

* The climax of the absurdity of dressing our unfortunate sepoys in ill-fitting imitations of European garments was attained when they were compelled to wear coarse and ill-made leather-boots *without stockings*.

627. Substances applied to skin, hair or teeth, with a veiw to the improvement of their appearance, are called **cosmetics.** They are frequently injurious to the structures to which they are applied, and sometimes poisonous to the system. Thus *flake-white, blanc de krems, blanc de vinaigre* are preparations of lead carbonate: *blanc de perle,* which ought to be bismuth subnitrate, is often adulterated with the same. Preparations of arsenic are used as depilatories. Hair-dyes often contain lead, generally the acetate, sometimes litharge; and mercurial salts are used in pomades &c. for the destruction of parasites.

CHAPTER VIII.

EXERCISE.

628. Disuse of any organ is followed by malnutrition or atrophy. Perfect health, therefore, requires the moderate EXERCISE of every constituent of the organism, muscles and nervous system included. By exercise of the voluntary muscles not only are their own integrity and sanitary condition maintained, but a healthy state of brain, digestive system and other secretory and excretory organs ensured. In this chapter will be considered the *effects* of voluntary muscular exercise, its *estimation* and its proper *regulation*.

629. The effect of exercise on the **respiratory** process is to increase considerably the amounts of air inspired and carbon dioxide expired. The volume of air required during a state of rest is quintupled during walking at the rate of four miles an hour or making equivalent exertion of any other kind.* In an ordinary day of work, more than three and a half ounces of carbon over the quantity excreted during a day of rest will be oxidized in the lungs, an excess of more than one-third.† Excessive exertion has, therefore, a tendency to produce congestion of the lungs; while deficiency of exercise promotes accumulation of carbonaceous matter and deposit of tubercle. The water expired is also increased, being nearly two and a half times as abundant in the former case as in the latter.

---

* The following are some of the results of Dr. E. Smith's experiments on the effect of exercise on inspiration. Taking the quantity of air inspired in a lying posture as unity, the quantities under other conditions were represented by the following numbers:—sitting 1·18, standing 1·33, singing 1·26, walking 1 mile per hour 1·90, ditto 2 miles 2·76, ditto 3 miles 3·22, ditto and carrying 34 lbs. 3·50, ditto and carrying 62 lbs. 3·84, ditto and carrying 118 lbs. 4·75, walking 4 miles per hour 5·00, ditto 6 miles 7·00, trotting on horseback 4·05, swimming 4·33, treadmill 5·50.

† The amount of carbonic acid expired in different circumstances is thus stated, in grains per minute, by Dr. E. Smith:—in sleep 4·99, lying down and almost asleep 5·91, walking 2 miles an hour 18·10, ditto 3 miles 25·83, at treadmill, ascending 28·05 feet per minute, 44·97.

630. The force and rapidity of the **circulation** are increased and, as a necessary consequence, the amount of blood supplied to all parts of the body. The pulse rises from 10 to 30 beats or more above its normal frequency; falling subsequently below it, even to the extent of 40 or 50 beats if the exertion have been continued and severe. During exercise, intermittence or irregularity of the heart's action shows that excessive effort is being made; rapidity and weakness of pulsation being, by themselves, compatible with safety. Very violent effort may produce rupture of the heart or of a large blood-vessel, while lower degrees of excess lead to both functional and organic disease. On the other hand, want of exercise promotes weakness, dilatation and fatty degeneration.

631. Increased action of lungs and heart produces congestion of the **skin**, which becomes red and excretes copiously water, common salt and various acids. So long as evaporation proceeds normally from the surface the temperature of the body is maintained at or little above its normal degree, but anything which checks evaporation tends to promote increase of heat and render continued exertion difficult. An atmosphere saturated with moisture, for instance, will prevent due cooling by evaporation from the skin and render exertion irksome.

632. The voluntary **muscles**, moderately exercised, grow in bulk and power: but, if over-tasked, waste. Rest is essential to the nutrition and repair of muscle, and even moderate effort too long continued induces deterioration of the tissue. The best exercises are those which bring into suitable play all the muscles of the body, without disproportionate stress on any one or any group. Walking briskly, riding on horseback, rowing and systematic gymnastic training fulfil these conditions.

633. Those parts of the **nervous system** which communicate between the will and the muscles and which supply these with motive power share in the benefit conferred by moderate exercise. Practised movements are more easily performed, action responding more promptly to volition and co-ordination of complex motions being more complete. The intellectual faculties undoubtedly require for their efficient action and cultivation such a healthy condition of the circulatory, respiratory and digestive apparatus as moderate exercise alone can give; but, beyond

the degree necessary to this end, though within the limit of excessive effort, muscular exercises will be performed at the expense of intellectual energy; not only because time, but still more because each individual's stock of nervous force is limited. The latter varies widely in amount and some men enjoy the possession of it in such abundance as to excel in athletic and also in intellectual pursuits: but, as a general rule, the distinguished pugilist, pedestrian or oarsman will not be remarkable for mental power. For a healthy state of the emotions, also, a due degree of physical exercise is essential, deficiency leading to morbid sensibility and to the disorders commonly called hysterical, sometimes to hypochondria. Excessive sexual feeling, being more dependent than other emotions on physical conditions, may be controlled by the derivation of nervous energy which great bodily exertion effects.

634. The **digestive organs** necessarily share in the advantages of the quickened circulation which exercise produces. All the processes of digestion are more actively performed; and food, demanded in greater quantities, is digested with greater rapidity than in a state of rest. The loss of carbon through the lungs requires to be repaired by carbonaceous food and for this purpose fats are instinctively preferred to carbo-hydrates. The profuse discharge of water through lungs and skin must also be compensated by drink, which it is better to take frequently in small quantities. Salts, especially chlorides and phosphates, are also expended and must be replaced by food. The alvine discharge is lessened in quantity by exercise, owing to diminution of water passing into the bowels.

635. The **urine** and the cutaneous secretion being in a manner complementary, the increase in the latter which exercise produces diminishes the quantity of the former. The sodium chloride is lessened also, for the same reason. The amount of urea is not increased by muscular exertion, but that of uric acid is. The alkaline phosphates are often much augmented, chiefly from expenditure of nerve tissue.

636. The principal **tissue-changes**, which take place during exertion appear to be the formation of paralactic acid in the muscles, which requires rest for its neutralization and removal; the loss of water from them; and the oxidation of carbon. The expenditure of nitrogen is but

little in excess of that which goes on during rest, so that the excess of carbon must be derived from fat or some other non-nitrogenous constituent of the muscular tissue. The general effect of the metamorphoses which take place is to diminish the weight of the body and cause an urgent demand for food and still more for water.

637. Professor Parkes concluded, from his own and others' experiments, that the **elimination of nitrogen** by the kidneys is but slightly affected by exercise: being probably lessened while the exercise proceeds and increased during the period of rest which succeeds exertion. In comparing eliminations in a day of rest and in a day of partly rest and partly work he found little or no difference; also that, when ordinary exercise followed two days of complete rest, elimination was diminished on the first exercise-day.

638. The effects of **excess** of physical exertion are illustrated by the case of Weston, during his unsuccessful attempt to walk 400 miles in five consecutive days. The weight of the body was diminished; temperature and pulse fell; there were little appetite and little sleep. On the third day there was drowsiness: on the fourth the pedestrian became giddy and his sight defective. On the fourth night he slept and had gained a little weight. His morbid condition is supposed to destroy the value of Dr. Flint's discovery that the excessive muscular exertion increased enormously the excretion of nitrogen.

639. The standard for ESTIMATION of physical exertion is either the *foot-ton* or the *kilogrammeter*: the former being the amount of effort necessary for raising one ton one foot in height; the latter, the amount required for raising one kilogram one meter and convertible into the former by multiplying by 0·003229.* It is possible to reduce the simpler forms, only, of exercise to this standard with any exactness; and it is still more difficult to lay down any rules for the amount of exertion necessary to health, because the effect upon the system of a given effort varies with the time in which it is performed, and also with the mental condition; rapid walking for instance, being more exhausting than slower movement and irksome labor than pleasant. A few facts, however, may be taken as sufficiently established for practical purposes.

640. 150 foot-tons may be considered as the minimum **amount** of exercise necessary to maintain the health of

---

* A kilogram $= \frac{2 \cdot 2046213}{2240}$ ton; and a meter $= 3 \cdot 2809$ feet; therefore a kilogrammeter (a kilogram raised one meter) $= \frac{2 \cdot 2046213}{2240} \times 3 \cdot 2809$ ton raised one foot $= 0 \cdot 003229$ foot-ton.

an adult man not undergoing more severe mental exertion than ordinary life or routine office-duties demand. 300 foot-tons represent an average day's work of a manual laborer, 400 a hard, and 500 a very hard, day's work. This last amount of labor may be, and often is, exceeded; but only for one, or at a most a few, days; prolonged rest and increased food being necessary for the repair of the exhausted nerves and muscles.

641. As to the estimation of different **kinds** of exercise it is clear that in ascending a height directly the weight of the whole body is raised the whole height; so that a man of 140 lbs. weight, climbing a ladder of 40 feet, without a load, would accomplish two and a half foot-tons. Walking on the level is equivalent to raising one-twentieth of the weight (say 7 lbs.) through the distance walked; so that a mile's walk represents 16·5 foot-tons. If a load of 40 lbs. be carried it will make an addition of 4·7 foot-tons for each mile; so that the work of a cooly carrying half a maund along 10 miles of level road may be estimated at 212 foot-tons. Taking 154 lbs. (11 stone) as the average weight of European male adults in this country, a mile's level walking represents 18·15 foot-tons, so that $8\frac{1}{4}$ miles would make up 150 foot-tons laid down as the minimum amount of daily exercise. A soldier's drill without arms is estimated as one-third more fatiguing than ordinary walking. A level march of 12 miles without load represents, for men of 154 lbs. weight, 218 foot-tons; but, if weights of 20, 40 or 60 lbs. are carried, the number would be 246, 274·5 or 303. In estimating prison-labor allowance must be made for the fact of its being punitive, which increases considerably its exhausting effect. Useless labor, too, as shot-drill, is much more oppressive than work which produces a useful and measurable result; while much more labor can be undergone by prisoners participating, even in very small proportion, in the profits accruing from manufactures.*

* Letheby gives the following estimates of different kinds of labor in foot-tons:—laborer carrying bricks (Mayhew) 1,627,200, coal-whipping (ditto) 1,774,221, ascending Faulhorn (Fick) 933,746, ditto (Wislicenus) 1,074,913, treadmill (Mayhew) 1,008,000, ditto (E. Smith) 865,166, turning a winch (Coulomb) 837,766, walking 20 miles (Haughton) 792,000, paving (Coulomb) 788,480, carrying loads 732,480, shot-drill (Haughton) 694,400.

642. Under the head of REGULATION of exercise *diet, training, gymnasia, marching* and *rest* have to be considered.

643. As regards **diet** the general principle must never be forgotten that increased exertion, bodily or mental, but the former more especially, requires increased food. It would seem to be unnecessary to state a fact so obvious; but experience shows that in dealing with soldiers, and still more frequently with prisoners,* ignorance or neglect of it has not unfrequently worked mischief. Soldiers marching or campaigning should have more food than soldiers at comparative rest in barracks; unless, indeed, (as is possible), their barrack dietary is in excess of sanitary requirements. Prisoners employed at real hard labor should be better fed than those undergoing simple imprisonment or the spinners, weavers &c. of some jails.

644. What has been said as to the effects of exercise indicates the **kind of food** needed to supply the waste. It must be carbonaceous, because the excretion of oxidized carbon is four times as great during exertion as in rest; and the fats are shown by experience to be preferable to the starches. Conversely, as exercise of the muscles is necessary for the elimination of carbon from the system, carbonaceous food should be diminished in a state of prolonged absence of exertion. There is also increased expenditure of nitrogen (though not to the extent formerly supposed), and this demands an increase of nitrogenous food; meat being better adapted to the purpose than leguminous seeds, because it is more easily digestible and contains more fat. The erbswurst (393), seems to possess fully the qualities required in a campaigning food. Alcohol, diminishing the excretion of carbon, the accumulation of which in the muscles incapacitates them for continued exertion, is inadmissible during exercise; except when a sharp stimulus to increased and final effort is required. The excretion of salts from kidneys and skin indicates increase of this element of food. Lastly, water is essential to the action of muscle, and small quantities at frequent intervals should always be allowed

* For instance a Jail Superintendent in this country has been known to reduce prisoners' food until arrears of labor should be made up.

during marches or other work: while the sudden ingestion of a large volume of cold water should be forbidden. When absolute exhaustion follows excessive exertion, food and drink should be cautiously administered in small doses at a time; strong beef-tea or solution of extract of meat with a little spirits or strong wine, and hot, being the best form of nourishment for the purpose.

645. **Training** is the systematic cultivation of the muscular and nervous systems for powerful effort and sustained endurance during a brief period of competitive exertion. It is almost entirely an empirical process; and though some of its rules are demonstrably injurious it has been on the whole successful and would have excellent effect upon the physical health of the persons subjected to it were it not that they, being generally men of low intellectual and lower moral power, too often compensate the restrictions of the period of training by unrestricted license after the exertion has been made. If not unduly prolonged—the usual period being about six weeks—the health is decidedly improved by the process. The capacity of the lungs is increased. The muscular movements are brought completely under the control of the will. The muscles themselves gain in size and firmness, all superfluous fat has disappeared, superficial injuries are little felt and quickly repaired, and health of body induces or is accompanied by cheerfulness and good temper.

646. There is little variation in the **rules** by which these results are obtained. The diet consists in large proportion of lean meat,* lightly cooked; fat is excluded as far as possible, sugar altogether; no spirits, and often no beer or wine, are allowed, the beer being weak or the wine diluted if either is admitted into the dietary; tea and coffee are looked on with suspicion and grudgingly allowed, water and barley water, and these in closely restricted quantities, being often the only drink permitted: most

* The following was King's dietary during training for his encounter with Heenan. *Breakfast*: two lean mutton-chops, somewhat under-done, with dry toast or stale bread, and one cup of tea without sugar. *Dinner*: 1 lb. or 1¼ lb. of beef or mutton, with toast or stale bread; very little potato or other vegetable; half a pint of old ale, or one or two glasses of sherry. *Tea*: one cup of tea without sugar, with an egg and dry toast. *Supper*: half a pint of oat-meal porridge or half a pint of old ale.

trainers forbid tobacco and all enjoin moderation in its use. As much time as possible is spent in the open air and the bed-room is cool and thoroughly ventilated. Exercise is moderate at first and gradually increased. The skin is maintained in healthy condition by frequent baths, profuse sweating being induced both by the exercise taken and by artificial means, as heaped bed-clothes or hot air baths.

647. Most of these rules are consistent with hygienic principles, and we must look to the **defects** of the system for explanation of the facts that its prolonged application is injurious, that its effect is transient, that the effort to which it is directed is often followed by extraordinary prostration and that return to a normal dietary is necessary to recovery of normal health. It is not difficult to see that the denial of fat to persons under training is one of the weak points of the system. The carbon which the muscles require not being supplied even by a sufficiency of carbohydrates in the food. The water, also, which the muscles demand is not given in adequate amount. It is probable that the improved hygienic conditions under which the athlete, during the period of training, lives, so far compensate these defects as to render the latter tolerable up to a certain degree, beyond which lies impairment of the vital powers.

648. No school for boys or girls and no depôt where young recruits are trained should be without a **gymnasium** where regular and graduated exercise of all the muscles, under careful scientific superintendence, can be had.

649. The **effects** of gymnastic exercises require to be watched both during their performance and afterwards. In the first place the atmosphere of the building in which they are carried on is especially liable to become vitiated, owing to increased excretion of carbon dioxide and cutaneous exhalations, and ventilation demands special attention. The action of the heart and lungs should be free and regular, unimpeded by the clothing and unembarrassed by over-exertion. Difficulty of breathing or excessive rise in the rate of the pulse, especially if rapidity be accompanied by feebleness and irregularity, should be followed by immediate suspension of the exercise until the normal action of heart and lungs is restored. Efforts should be

increased gradually, practice rendering feats easy of accomplishment, without danger or inconvenience, which would have been productive of both if attempted at first. The exercises should be varied, not only that they may be less fatiguing but also that all the muscles may in turn be exerted and may be symmetrically developed. So long as they continue there is no danger of chill and its consequences; but the fall of bodily temperature which follows cessation, along with the cooling due to evaporation from the surface, require attention. Additional clothing must be put on, dry flannel garments being the best.

650. The **subsequent** and permanent effects of a judicious course of gymnastic training will be improved digestion and appetite, sound sleep, expansion of the chest, increased size and firmness of the muscles, greater ability for sustained exertion without fatigue. If these results fail to follow the use of the gymnasium it is to be inferred that the exercises are either excessive or ill-arranged.

651. A well-managed **march** is eminently conducive to health; involving as it does a moderate and regular amount of daily exercise with a sufficient supply of wholesome food. No spirits should be issued; but malt liquor or light wine may form part of the ration. Nightly sleep should be interfered with as little as possible and, therefore, afternoon marches are preferable to morning. The weight to be carried by the soldier should be reduced to the utmost, and what is inevitable should be so arranged as to be most conveniently borne and to impede his movements least. His socks and boots should fit so as not to gall the feet and his other garments should be loose and free. It should be remembered that the stiff marching of the parade-ground is more fatiguing than the easy style, in open order, suitable to the line of march;* and quick marching with occasional halts for rest are less trying than a slower rate of movement without stopping. Finally, sufficient provision must be made for repair of exhausted muscular tissue by occasional halts. By attention to these conditions very long marches at a rate of 10

---

* The foot should be firmly planted, nearly but not quite flat, upon the ground, the heel first, and not moved until raised for another step. It should be lifted as little as possible from the ground.

to 15 miles a day can be made, not only without deterioration but even with positive improvement of health.

652. **Rest** is essential to the repair of the nervous, muscular and other tissues which exercise tends to exhaust; not only relief from labor but sleep. Increase of work requires increase of rest. Inattention to these facts has led to excessive sickness and mortality in armies and to the bad consequences which have so often followed upon over-exertion in individuals. The soldier's sleep should be broken by night duty as little as the exigencies of his service render possible. On marches, a weekly halt may be sufficient in the beginning; but, as the effort is prolonged and fatigue increases, it will be desirable to halt, in addition, after every four or even three stages. In gymnasia the first symptoms of exhaustion of heart or voluntary muscles must be followed by immediate rest. Finally, severe mental labor demands, even more urgently, than bodily fatigue, the rest which sleep bestows.

CHAPTER IX.

CLIMATE AND METEOROLOGY.

653. The CLIMATE of a place is its condition with respect to the *temperature*, *humidity*, *pressure*, *movement* and *electrical state* of the atmosphere; and METEOROLOGY is the science of observation by which climate is ascertained. In this chapter each of these elements of climate (except the last) will be considered with reference to the circumstances which produce or modify it, its relation to health and disease, and the instruments and methods of observation which it requires.

654. The TEMPERATURE at any place depends primarily on the quantity of solar heat absorbed and radiated by the soil and by the moisture present in the atmosphere.* Certain circumstances modify this quantity; of which the principal are;—*latitude*, *elevation*, quantitative relation of *land and water*, character of the *surface*, existence of *currents* either of air or of water, and *rainfall*.

655. Between the tropics the sun is always vertical somewhere; and nowhere do the solar rays strike the surface at noon with any considerable degree of obliquity. In the low **latitudes** of the torrid zone, therefore, the greatest quantity of solar heat is received, and the lower the latitude, (if other things be equal), the higher will be the mean temperature†. Owing to disturbing causes, however, the fall in temperature is not gradual or regular as the latitude increases.

656. **Elevation** above sea-level reduces temperature. The air being heated, not by the solar rays which pass through it but by radiation from land or water, the strata nearest to the general surface must be the warmest and

---

* The earth's central heat, which produces a rise in the thermometer of 1° C. for every 29 meters of depth below the surface has no appreciable effect on climate, owing to the low conducting power of the earth's crust.

† The mean annual temperature of places lying on the equator itself is estimated at 82° F.; of the poles at 2°·5 F.

heat will diminish in proportion to height. A hill or range of hills, therefore, will be cooler than the plain from which they rise. Again, the greater the elevation, the less the mass of heat-absorbing matter and the more rapid its radiation into space. At the greater heights, also, there will probably be less atmospheric moisture to absorb and radiate the heat proceeding both from the sun and by radiation from the earth.*

657. The relative amounts of **land and water** influence temperature to a powerful degree; the more the latter preponderates the lower being the mean temperature and the more equable the climate. Land absorbs, and therefore radiates, heat more readily than water. Its specific heat, also, being very much lower than that of water, its temperature rises higher in a given time of exposure to solar heat; so that while a thermometer placed on the ground in a hot country may rise to 160° F., (or even to 237° F. if protected from air currents), the temperature of surface-water rarely exceeds 82° F; and the air immediately above it will be cooler still by from two to five degrees. Heating during the day and cooling during the night being, then, more rapid processes in the case of land than in that of water the diurnal and annual ranges of temperature will be less in insular and coast positions than in the interior of continents.†

658. The nature of the **soil** and its effects upon temperature have been already considered in Chapter V. Some soils absorb heat and give it out more abundantly than others. Bare surfaces will heat the air more and more quickly than those clothed with vegetation. Evaporation from water or from wet surfaces, like marshes or the banks

* Observations on aerial temperature, made in balloon-ascents, show progressive but not uniform or regular diminution.

† Mr. Drew quotes the following passage from a paper of Mr. Glaisher's—"At times of extreme temperature, the effect of water upon the temperature of the air is very great. On February 12, 1847, the temperature of the air at my house, situated one mile and a half from the river, was 6°; the lowest reading 32 feet above the water of the Thames was 16°; the temperature of the water was 33°; its heating effect upon the air in its immediate vicinity amounted to 10°; at the Observatory the reading was 10°·5; and the heat of the water of the Thames seems to have influenced the temperature of the air at the Observatory to the amount of 4°."

of tidal streams, cools. The shelter of hills or high rocks may lower the temperature of certain spots by diminishing the duration of exposure to the solar rays or by keeping off a chilling wind.

659. **Currents**, aerial or oceanic, are well known to modify temperature. The hot land-wind, the cool sea-breeze, the trade-winds blowing from polar towards equatorial regions, are familiar instances of the former; the gulf-stream of the latter. Winds may act indirectly also upon temperature, by bringing up clouds which either fall in rain or absorb heat, solar and terrestrial.

660. The **rainfall** probably raises the temperature of cold countries by giving out the heat which had become latent when the water of inter-tropical seas was evaporated, to be afterwards condensed and fall as rain. In hot climates this effect is generally outweighed by the cooling which the conversion of heat-absorbing aerial moisture into water produces, and by the cooling effect of evaporation from the wet surface of the soil. With us, therefore, rainy seasons are generally cool.

661. In considering the effects of temperature on **health** we may dismiss those of cold with the brief remark that, with sufficient clothing and abundance of well-chosen food, a low temperature is certainly not detrimental and is probably beneficial to healthy adults. The effects of high temperature may be the result of direct action of the sun's rays or of heat simply. Sudden changes, especially rapid falls, are often injurious.

662. It may be taken as established that a rise of 13° F. above the normal temperature of the blood is necessarily fatal to vertebrated animals, either by coagulation of some of the albuminous fluids or by action upon the nerve-centres or by both; and as a thermometer exposed to the sun's rays will not unfrequently rise above 110° F. even in comparatively high latitudes, death by **direct insolation** in hot climates might be expected to occur oftener than it does. Owing, however, to the natural protection afforded by evaporation from the surface and to the artificial safeguard of clothing, this result is very rare; unless either a highly heated atmosphere, more or less charged with moisture, or great bodily exertion concur. Thus in the open sea or at great elevations on land, though the direct

power of the solar rays is in the former case not less and in the latter greater than on land at average levels, yet this form of sunstroke is most uncommon, because aerial temperature is under those circumstances not excessive. Copious evaporation is a necessary effect of direct solar heat; and if from excess of the latter or of humidity in the atmosphere that process is insufficiently maintained the temperature of the body must rise, and may rise to a point incompatible with continued life.

663. A slight rise of bodily **temperature** (from half to one degree F.) is one effect of increased atmospheric heat, observable in transition from a temperate to a hot climate. Taking the normal temperature of the body in England at 98°·30 Fahrenheit it was found to be 98°·66 Fahrenheit within the tropics; and 99°·02 at the equator, the thermometer standing at 84°. There seems to be a slight but regular increase of bodily, proportional to rise of aerial, temperature, each degree of the latter corresponding to 0°·05 of the former. This effect takes place even when external and internal heat, on the one hand, and radiation from the body, evaporation from skin and lungs, and movement of air, on the other, maintain the equilibrium of health. When, however, excessive humidity interferes with free evaporation, the temperature of the body rises and may increase to a dangerous extent. In the well-known experiments in which the effects of exposure to a heated atmosphere in ovens were tried it was found that a temperature of 260° F. could be borne, without injury or serious discomfort and with a rise of but 2°5 degrees of bodily heat, provided the air was dry and therefore free evaporation from the skin and lungs possible; but that in a moist atmosphere the temperature increased by 8°. The effects of intertropical heat, then, in raising the temperature of the blood are partly constant and partly dependent upon atmospheric humidity.

664. The function of **respiration** is less actively performed in a hot than in a temperate climate. The number of respirations is diminished, less carbon and less water by about one-fifth are eliminated by the lungs. Not only is less air by 18 per cent. respired in a given time but that which is taken into the lungs, being rarified by heat, contains less oxygen in a given volume than in cooler places. Thus it is estimated that 9 per cent. less oxygen

is inspired at 80° F. than at 32°. The respiratory capacity, however, of the lungs is increased and they weigh less in hot than in cold climates.

665. The action of the **heart** is diminished under the influence of a hot climate. **Digestive** power is accommodated to the altered conditions of the system; it is less powerful and there is less appetite, because there is less demand for food. The activity of the perspiratory and sebaceous glands of the **skin** is much increased; the papillæ being often morbidly developed into the state of "prickly heat." Some change sometimes takes place, after protracted residence, in the pigmentary layer, producing the yellowish tinge supposed to be characteristic of "old Indians." Owing to increased action of the skin the quantity of **urine** is diminished; and also that of excreted sodium chloride. Less food yields less urea. Some European residents complain of want of energy and other results of a depressed condition of the **nervous** system; but there is strong reason to believe, and abundant illustration by example, that as much and as good work, bodily or mental, can be done in this country as in Europe; and that the want of definite employment and the habits of indolence and self-indulgence which that want engenders are more to blame than climate for lack of energy and wasted lives.

666. **Insolation** is much more frequently a result of a highly heated atmosphere* than of direct solar action: but in this case also other causes almost invariably contribute to produce the affection. These are stagnation and impurity of the air, deficient evaporation from lungs and skin, and physical exertion; the two former failing to diminish the temperature of the body which the last aggravates. With the forms and therapeutic management of insolation we are not here concerned. When high external temperature renders its occurrence probable, cold baths, the use of punkahs and rest are preventives generally available and usually successful.

671. The effects of **season** upon health may be briefly noticed here, although temperature is only one of the climatic factors in their production. It is observed that

* It is doubtful if insolation occurs at a temperature lower than 98° F.

thoracic affections prevail most in the cold months and in direct proportion to the lowness of the temperature; abdominal complaints in summer, varying with heat and dryness. Cholera, in Europe at least, is favored by a high temperature and is most destructive in August and September. Variola, on the contrary, is a disease of winter and spring, and its progress is checked by increased heat.

668. Sudden falls of temperature or considerable ranges, diurnal or annual, or rapid **alternations** of heat and cold are more trying to the constitutions of men and other animals than continued residence in a climate of temperature steadily high. To guard against the effects of such vicissitudes clothing and dwellings should be capable of such modification as circumstances require; and the food in quality and quantity must be adapted to temperature and amount of exercise, according to the principles already laid down.

669. The question of **acclimatization**, whether of an individual or of a race, in a country hotter than its own has been much discussed. We have seen that Europeans passing from temperate to intertropical regions undergo certain definite changes in bodily constitution, which are permanent so long as they continue to reside in the latter. We may consider these changes as beneficial adaptations to altered climatic conditions; in other words as steps towards acclimatization; and it is highly probable that if the practices and habits which are under the control of the will were similarly modified by the immigrants, as high a standard of general health could be maintained in India as in Europe. The death-rate of foreigners in military occupation of a country, and that country one in which cholera and malarial diseases are endemic and through which epidemics of variola sweep almost unchecked, will always remain higher than amongst the corresponding classes in their own land; but we know that that portion of the excess of mortality which is not inevitable has been largely reduced by improved habits of life and increased attention to sanitary considerations; and we look forward with confidence to its ultimate extinction. As to the larger question of the possibility of acclimatization of a race, it has been laid down that none will survive transplantation to a climate whose mean temperature exceeds its own by 20° F. That such a transition will produce well-marked

modifications in physical and mental constitution is more than probable, and that the descendants of the original immigrants will present peculiarities both of body and mind which will distinguish them, as a race, from the original stock, is in conformity with experience; but, even when the new conditions of existence are much more unfavorable than those involved in a high degree of mean temperature, the action of natural selection and the survival of the fittest will ensure the perpetuation of *a* race, though perhaps in some qualities degenerate.

670. The **chief points** to be ascertained, so far as heat and cold are concerned, are the *mean temperature*, the *range* and the *extremes*. The necessary observations for ascertaining these are made with thermometers of various kinds, which will be described presently. These instruments must be most carefully constructed and compared with Observatory standards.

671. Three **scales** are in common use in different parts of the world. In the United Kingdom, in the United States, and in British India the Fahrenheit scale, according to which the temperature of melting ice is 32°, and that of the steam of water boiling under barometrical pressure of 30 inches, is 212°, is universally employed for meteorological purposes. Celsius' thermometer, commonly called the Centigrade, which indicates 0° and 100°, respectively, at those temperatures, is used in all scientific work in France and in laboratories almost everywhere. Réaumur's scale is employed in Germany, Russia and Spain for all purposes, and in France for domestic use. In it 0° indicates the same temperature as in the centigrade, but the boiling point of water is 80°.*

672. The true **mean temperature** of the air for any day is obtained by adding together the degrees, observed

* Tables for the conversion of degrees on any one of these three scales into the corresponding degrees of either of the others will be found in almost any systematic work on any branch of Physics. In the absence of such aid the following formulæ may be found useful. The negative sign of degrees below zero must be carefully attended to. $C^\circ = \frac{5\,(F^\circ - 32)}{9}$. $R^\circ = \frac{4\,(F^\circ - 32)}{9}$. $F^\circ = \frac{9\,C^\circ}{5} + 32$. $F^\circ = \frac{9\,R^\circ}{4} + 32$. $C^\circ = \frac{5\,R^\circ}{4}$. $R^\circ = \frac{4\,C^\circ}{5}$.

to tenths, of the dry-bulb thermometer, noted hourly, and dividing the sum by 24. This thermometer should be so placed in the shade as to be unaffected by radiation from walls &c. or by evaporation from the wet-bulb; and its bulb, freely exposed to the air, should be 4 feet from the ground. Suspension from a slight wooden frame standing in a shed with double-sloping thatched roof, open completely at the ends and at the lower part of the sides, with no trees or buildings close by, will best fulfil the conditions necessary for accurate observation of this and the other shaded instruments. The monthly mean temperature is the sum of the diurnal means divided by the number of days in the month; and the annual, the sum of the monthly means divided by 12.

673. Hourly observations being always inconvenient and often impracticable, other methods have been discovered which give **approximately** the daily mean temperature. The time for a single observation which should nearly correspond to this is different at different places, but a very close approximation, rarely more than 0°·3 or 0°·4 in excess of the true mean, may be made by dividing by four the sum of the minimum (681) temperature noted and the degrees observed at 10 A.M., 4 P.M. and 10 P.M.—these being the regular hours of observation at all Madras Meteorological Stations.

674. A still closer approximation to the true mean daily temperature, and one sufficiently accurate for all practical purposes, is obtained by means of the subjoined table from the maximum (680) and minimum temperatures and two or more other observations taken at any hours of the day or night.

675. TABLE OF MADRAS HOURLY RANGE FACTORS FOR DRY-BULB THERMOMETER.*

Hour.	January.		February.		March.		April.		May.		June.	
Maximum	−0·51	−0·49	−0·48	−0·48	−0·49	−0·50	−0·52	−0·54	−0·55	−0·57	−0·58	−0·58
Minimum	+0·49	+0·51	+0·52	+0·52	+0·51	+0·50	+0·48	+0·46	+0·45	+0·43	+0·42	+0·42
4 A.M.	+0·41	+0·41	+0·42	+0·43	+0·44	+0·44	+0·43	+0·42	+0·41	+0·40	+0·39	+0·38
5 "	+0·45	+0·45	+0·46	+0·47	+4·47	+0·46	+0·45	+0·44	+0·43	+0·42	+0·41	+0·41
6 "	+0·49	+0·50	+0·51	+0·51	+0·51	+0·49	+0·46	+0·44	+0·42	+0·41	+0·40	+0·40
7 "	+0·43	+0·44	+0·46	+0·45	+0·42	+0·37	+0·30	+0·25	+0·23	+0·24	+0·26	+0·28
8 "	+0·19	+0·20	+0·20	+0·18	+0·15	+0·10	+0·05	+0·01	0·00	+0·03	+0·07	+0·11
9 "	−0·08	−0·07	−0·08	−0·09	−0·11	−0·14	−0·18	−0·19	−0·19	−0·16	−0·11	−0·07
10 "	−0·29	−0·28	−0·27	−0·27	−0·28	−0·31	−0·34	−0·35	−0·36	−0·34	−0·27	−0·23
11 "	−0·41	−0·40	−0·39	−0·39	−0·41	−0·41	−0·40	−0·41	−0·48	−0·47	−0·41	−0·36
Noon	−0·48	−0·47	−0·46	−0·45	−0·45	−0·47	−0·51	−0·53	−0·55	−0·54	−0·52	−0·49
1 P.M.	−0·50	−0·49	−0·48	−0·48	−0·49	−0·50	−0·51	−0·53	−0·55	−0·55	−0·56	−0·56
2 "	−0·48	−0·48	−0·48	−0·48	−0·48	−0·48	−0·49	−0·50	−0·51	−0·53	−0·56	−0·57
3 "	−0·45	−0·45	−0·46	−0·46	−0·45	−0·44	−0·45	−0·45	−0·45	−0·46	−0·50	−0·53
4 "	−0·38	−0·39	−0·40	−0·40	−0·39	−0·37	−0·36	−0·35	−0·35	−0·37	−0·40	−0·43
5 "	−0·26	−0·28	−0·31	−0·30	−0·28	−0·25	−0·22	−0·20	−0·20	−0·21	−0·24	−0·27
6 "	−0·13	−0·14	−0·15	−0·16	−0·15	−0·11	−0·07	−0·04	−0·02	−0·03	−0·06	−0·10
7 "	−0·04	−0·05	−0·06	−0·06	−0·04	0·00	+0·05	+0·08	+0·09	+0·08	+0·07	+0·05
8 "	+0·02	+0·01	0·00	0·00	+0·02	+0·05	+0·10	+0·13	+0·15	+0·14	+0·13	+0·11
9 "	+0·06	+0·06	+0·06	+0·06	+0·07	+0·09	+0·13	+0·16	+0·18	+0·18	+0·17	+0·17
10 "	+0·11	+0·11	+0·10	+0·10	+0·11	+0·13	+0·16	+0·19	+0·21	+0·21	+0·20	+0·19

* Taken with Mr. Pogson's permission from his Meteorological Reduction Tables.

Hour.	July.		August.		September.		October.		November.		December.	
Maximum	−0·58	−0·57	−0·57	−0·56	−0·56	−0·55	−0·53	−0·52	−0·51	−0·51	−0·52	−0·52
Minimum	+0·42	+0·43	+0·43	+0·44	+0·44	+0·45	+0·47	+0·48	+0·49	+0·49	+0·45	+0·48
4 A.M.	+0·38	+0·38	+0·39	+0·39	+0·38	+0·39	+0·42	+0·43	+0·42	+0·42	+0·42	+0·42
5 "	+0·41	+0·41	+0·42	+0·42	+0·42	+0·43	+0·44	+0·45	+0·46	+0·46	+0·46	+0·46
6 "	+0·41	+0·42	+0·43	+0·44	+0·44	+0·45	+0·47	+0·48	+0·49	+0·49	+0·48	+0·48
7 "	+0·29	+0·31	+0·32	+0·32	+0·32	+0·32	+0·33	+0·34	+0·35	+0·37	+0·42	+0·44
8 "	+0·13	+0·14	+0·13	+0·13	+0·14	+0·13	+0·11	+0·09	+0·09	+0·12	+0·15	+0·18
9 "	−0·04	−0·03	−0·04	−0·04	−0·05	−0·06	−0·09	−0·12	−0·15	−0·14	−0·13	−0·11
10 "	−0·21	−0·20	−0·20	−0·21	−0·22	−0·24	−0·27	−0·29	−0·31	−0·32	−0·33	−0·31
11 "	−0·34	−0·34	−0·35	−0·37	−0·38	−0·39	−0·40	−0·41	−0·42	−0·44	−0·42	−0·42
Noon	−0·46	−0·46	−0·47	−0·48	−0·49	−0·49	−0·48	−0·48	−0·48	−0·48	−0·49	−0·49
1 P.M.	−0·55	−0·55	−0·55	−0·55	−0·55	−0·54	−0·53	−0·52	−0·51	−0·51	−0·51	−0·51
2 "	−0·58	−0·57	−0·56	−0·56	−0·55	−0·54	−0·52	−0·50	−0·49	−0·49	−0·50	−0·49
3 "	−0·54	−0·54	−0·53	−0·51	−0·49	−0·47	−0·46	−0·44	−0·43	−0·44	−0·45	−0·45
4 "	−0·44	−0·44	−0·43	−0·41	−0·38	−0·37	−0·37	−0·36	−0·34	−0·34	−0·35	−0·37
5 "	−0·29	−0·31	−0·31	−0·29	−0·26	−0·24	−0·26	−0·25	−0·22	−0·21	−0·23	−0·25
6 "	−0·12	−0·14	−0·14	−0·12	−0·10	−0·09	−0·10	−0·10	−0·08	−0·07	−0·10	−0·12
7 "	+0·02	+0·01	+0·01	+0·01	+0·01	0·00	+0·02	+0·02	+0·01	0·00	+0·01	+0·03
8 "	+0·10	+0·09	+0·08	+0·08	+0·07	+0·06	+0·04	+0·03	+0·04	+0·04	+0·03	+0·03
9 "	+0·16	+0·15	+0·14	+0·13	+0·12	+0·11	+0·10	+0·08	+0·07	+0·07	+0·07	+0·07
10 "	+0·18	+0·18	+0·18	+0·17	+0·16	+0·15	+0·14	+0·13	+0·12	+0·12	+0·12	+0·12

676. The **use** of this table will be explained best by an example. Suppose that on the 22nd May the minimum temperature was 85°·5, the maximum 105°·6, and the readings taken at 10 A.M. and 10 P.M. were 104°·9 and 86°·0. The day being in the latter half of May the right hand column of the two under May is to be used. In it we find, corresponding to minimum, maximum, 10 A.M. and 10 P.M., the following factors: + 0·43, − 0·57, − 0·34 + 0·21. The sum of these factors divided by four gives the mean factor − 0°·07; which multiplied by the range (20°·1) is the required correction 1°·4, to be applied to the mean of the four observations, 95°·5. Hence 95°·5 − 1°·4 = 94°·1, is the approximate mean daily temperature for the supposed 22nd May. The greater the number of readings taken, besides the maximum and minimum, the nearer the approximation; but for sanitary purposes two observations will be sufficient. If there be a choice of hours of observation those should be selected whose factors yield an algebraic sum as nearly as possible = 0.

677. It was stated above (673) that the mean of the minimum and the three ordinary readings at 10 A.M., 4 P.M., and 10 P.M., is a close approximation to the daily mean temperature. From 9th August to 28th September the mean thus determined is strictly true; at other times a **correction** is necessary which, however, at no time exceeds 0°·5. The range for the day is multiplied by a certain factor, (retaining only tenths of a degree in the product), and the result subtracted from the approximate mean. From 29th September to 25th November the factor is 0·01;* from 26th November to 14th January 0·02; and from 15th January to 8th August 0·01:* being (as before stated) 0·00 for the remainder of the year.

678. Instead of correcting each daily mean in order to arrive at a true monthly or **half-monthly mean**, corrections may be applied to this as calculated from the uncorrected daily means. The range for the month or half-month is multiplied by the factor appropriate to the time of year, as given in (677), and the product subtracted as before from the approximate mean.

679. The **range**, diurnal, monthly or annual, is the difference between the maximum and minimum indications of the dry bulb thermometer in the day, the month or the year; the mean monthly range is the sum of the daily range divided by the number of days in the month: the mean annual range the sum of the mean monthly ranges divided by 12. These give the most important indications of climate for sanitary purposes. The range is ascertained by self-registering maximum and minimum thermometers.

680. The **shade maximum** thermometer is mercurial, with a contraction near the neck of the bulb, which

---

* Multiplying the range by 0·01 is merely moving the decimal point two places to the left, retaining the nearest tenth of a degree.

narrows considerably the opening between the latter and the stem. After the greatest degree of heat that part of the mercurial column which has passed above the contraction remains in the stem, while the portion nearer the bulb sinks, the continuity of the column being broken. The extremity of the detached part farthest from the bulb marks, therefore, the highest temperature reached. When this has been registered the continuity of the mercurial column is restored by shaking, swinging or tapping the instrument. The thermometer is placed nearly horizontally with the bulb slightly lowered. The maximum temperature of the day occurs between 1 and 2 P.M.*

681. The **shade minimum** thermometer is alcoholic,† fixed nearly horizontally but with the bulb an inch lower than the other end. A small steel index or needle moves freely within the tube: the instrument is set by gently inclining it until the upper extremity of the index is near the free surface of the spirit. As the latter contracts the index is carried down with it; but after the greatest degree of cold has been reached and the spirit again expands it does not raise the needle, which, therefore, shows the minimum temperature attained. The end of the index farther from the bulb is the indicator. The coldest time of the 24 hours is between 5 and 6 A.M., just before sunrise.

682. Two **extremes**, the greatest and least temperatures in shade, which give the ranges and which are the most important for our purpose, have been considered. Three others require notice—the maximum temperatures in sunshine and the minimum just above the surface of the ground. The former are ascertained by the Sun Maximum or Solar Radiation thermometers; the latter by the Grass Minimum or Terrestrial Radiation thermometer.

683. The **solar radiation** thermometers are made on the same principle as the shade maximum (680); but their bulbs are blackened to favor absorption of the sun's rays: one, for observing the maximum *in vacuo*, is enclosed

* Maximum thermometers sent to this country, even when professedly examined and corrected, almost always show an error by excess of one to two degrees. The minimum thermometers err also, but in the other direction.

† Mercurial minimum thermometers are useless.

in a glass case from which air is excluded, to shelter it from atmospheric currents. The other has a naked bulb and its indications are much more important for our purpose. Both may be placed either near the ground or at the same height as the other instruments, fully exposed to the solar rays.

684. The **terrestrial radiation** thermometer indicates amount of cooling due to radiation from the earth. It is a minimum thermometer like that described in (681) and is placed on the grass close to the ground.

685. It is evident that mean temperature, monthly or annual, is but of secondary importance as an indication of climate; because **changes** towards heat and cold may be very great in one place and trifling in another, yet may so counterbalance each other in both as to give nearly the same mean. These changes are of two kinds; namely *fluctuations*, which are regular and periodic, and *undulations*, which are irregular and non-periodic.

686. **Fluctuations** depend upon the earth's diurnal and annual motions, that is, on the alternations of day and night and of the seasons. The **diurnal** fluctuation is greater on land than on water, inland than on coast, in elevated places than at sea-level. On land, therefore, it is least on the shores of inter-tropical islands, as Ceylon and Singapore. The hottest time of the 24 hours has been already stated to be between 1 and 2 P.M., the coldest between 5 and 6 A.M., the rise or fall of temperature between these extremes being nearly uniform. This applies to land stations; the maximum and minimum taking place about an hour later at sea. The maximum does not coincide with but follows the culmination of the sun, on account of the slow and gradual absorption of the sun's heat by the earth, on which the temperature of the air depends.

687. The **annual** fluctuations depend on the position of the earth in her orbit, according to which days are longer or shorter and more or less solar heat is absorbed in a given number of days. These also are greater on land than at sea, are greatest in the interior of extra-tropical continents and least at sea-level between the tropics; as, for example, at Singapore, where the annual fluctuation does not exceed 3° or 4°. They are greater as we advance towards the

poles because of the greater obliquity with which the sun's rays strike the earth and because the differences of length between day and night increase; in the northern hemisphere, besides, there is a great preponderance of land, increasing absorption and radiation. As the diurnal, so the annual maxima and minima are not coincident with, but consecutive to, those relative positions of earth and sun which are most efficient in their production and they occur, not in June and December, but in January and July.

688. **Undulations** of temperature are caused by winds, clouds, rain, or other non-periodic agents, cooling by evaporation or heating by radiation. These, like the fluctuations, are least in tropical countries near the sea. In different places their amplitude may exceed or be less than that of the fluctuations.

689. Climates are **divided** into *continental* and *insular* according to the amplitude of their annual fluctuations or, in other words, to the range of their January and July mean temperature.* When the range is great the climate is continental, as in Siberia where (in Yakutsk) it is 114°·4; when it is small, as in part of Guiana where it does not exceed 2°·2, the climate is insular. "Extreme" and "limited" are sometimes used in the same sense as continental and insular. It must be remembered that a position on an island or a coast may have a continental climate; as, for instance, Alten on the coast of Norway (70° N. lat.) where in one year the annual range was more than 20°: and so, too, insular climates may exist in the inter-tropical interior of continents. A climate is *equable* when the undulations are trifling and *excessive* when they are great. As a general rule insular climates are equable and continental excessive.

690. Climates are represented on **maps** by curves passing through all places which agree in certain means of temperature. *Isothermal* lines pass through those points which have the same mean annual temperature; *isothermal* though those agreeing in summer temperature, *isocheimenal*

* Humboldt's classification of climates by isothermal lines is as follows:—1, hot 81° to 77° F.; 2, warm 77° to 68°; 3, mild 68° to 59°, temperate 59° to 50°; 5, cold 50° to 41°; 6, very cold 41° to 32°; glacial below 32°.

in winter temperature; June, July, August being the summer and December, January, February the winter months.

691. It only remains, so far as temperature is concerned, to notice briefly the effect of solar heat below the surface. This varies, as we have seen, with the nature of the soil; dry soils, for instance, showing a wider diurnal or annual range than clayey or others which retain water. Thermometers should be sunk in the ground and their indications accurately registered. It will be found that the deeper the instrument the later will the annual extremes be reached; so that, for example, in one instance where the thermometer was placed at a depth of 25½ feet from the surface the highest reading occurred in January and the lowest in July. It is found, also, that the deeper we descend the more equable is the temperature; so that ultimately we should arrive at a point where the influence of the sun's rays is not felt at all* and the degree indicated by a thermometer would be the same at all seasons. This "stratum of invariable temperature" is at different depths at different places; and below it the temperature increases as we descend.

692. The air is never completely dry, *evaporation* being continually going on from the surface both of land and water. Atmospheric HUMIDITY exists either in the condition of *vapor*, when it is invisible; or condensed into water in the forms of *dew*, *cloud*, *fog* and *rain*; or condensed and frozen as *hail* and *snow*.

693. The rate of **evaporation** from a given surface varies with the temperature of the air, the state of the wind, the amount of moisture already present in the atmosphere, the nature of the surface itself and its exposure to solar action. The greater the heat the freer the evaporation, other things being equal; but the latter increases more rapidly than in proportion to the rise of temperature, because heat acts not only by promoting vaporization but also by augmenting the capacity of the air for humidity. Wind favors evaporation by replacing air more or less

---

* A thermometer sunk 91 feet below the foundations of the Paris Observatory has steadily indicated a temperature of 53° F. for seventy years—two degrees above the mean annual temperature of the air above.

nearly saturated by drier air, unless the current be itself moister than the air which it removes. The less the moisture already present above the evaporating surface the more rapid is evaporation : the process becoming gradually slower as saturation is approached. The shade afforded by trees, hills, buildings &c. diminishes evaporation; and finally, a moist soil yields more vapor in a given time than an equal surface of water.*

694. The quantity of aqueous **vapor** which a given volume of air is capable of holding in solution varies with temperature; but is not directly proportionate to it. For example a cubic foot of air at 40° F. can retain 2·86 grs. of vapor; at 50°, not 3·57 grs. but 4·10 grs.; at 60°, not 4·29 grs. but 5·77. It follows not only that saturated air, if cooled at all, must deposit moisture but also that the meeting of two currents of different temperatures, each (whether saturated or not) capable of retaining its own moisture, may lead to deposition of water; and, if both are saturated, must produce that effect. Thus, if a saturated volume of air at 40° meet another, also saturated, at 60°, the temperature of the intermixed volumes will be 50°, the mean; but the quantity of aqueous vapor which can be retained will not be 4·315 grs. per cubic foot, the mean of the quantities in the original volumes, but 4·100 grs. 0·215 grs., therefore, will be condensed from each cubic foot of the combined currents and will become visible as cloud. Should this condensed vapor meet with air not saturated, it will be reabsorbed, partially or wholly according to the capacity of the latter.

695. Atmospheric humidity is either **absolute** or **relative**, the former being the total quantity of aqueous vapor in the air at a given time; the latter the percentage of saturation; that is, the ratio per cent. of the quantity present to the quantity which might be retained at the existing temperature. Relative humidity is much more important for our purpose than absolute.

696. When air containing aqueous vapor is cooled by contact with the surface of the ground to a point below that at which it can retain its moisture, the latter is con-

* The annual amount of water evaporated from inter-tropical seas is variously estimated at from 80 to 130 inches or more from 1 square inch of surface.

densed on the cooling surface as **dew**. It is deposited at night or in the evening, when the supply of solar heat has been withdrawn or so diminished as not to counterbalance cooling by radiation. Whatever favors this process promotes the deposition of dew, as absence of clouds, distance from trees or buildings. Movement of air is unfavorable, because it removes partially cooled particles before they have been sufficiently chilled to deposit. Good conductors, as metallic bodies, do not generally exhibit dew, because they receive continuous and rapid supplies of heat from the earth. Foliage and fibrous structures like clothing, being good radiators and bad conductors, receive the most copious deposit; to which a moist atmosphere and a still and cloudless night are most conducive. Dew frozen after deposition is **hoar-frost**.

697. The **dew-point** is the temperature at which the air begins to deposit its moisture. If we compare equal volumes at the same temperature that containing more vapor will have the higher dew-point; in other words a smaller depression of temperature will be sufficient to produce condensation. So, too, of equal volumes at different temperatures but equal in absolute humidity the cooler will need less depression for deposit than the other. The dew-point may be the same at very different degrees of air-temperature; and the state of the atmosphere with respect to dryness depends upon the greater or less depression of the dew-point below the temperature of the air at the time. Air saturated at one temperature may hold less moisture than non-saturated air at another temperature when the dew-point at the latter is higher than at the former. Complete saturation, when dew-point and air-temperature coincide, is comparatively rare. In general the atmosphere is capable of retaining more moisture than it has and the dew-point is below the actual temperature.

698. When saturated air is lowered in temperature its vapor is condensed into extremely minute particles of water, constituting **cloud** and sometimes fog. Visible clouds do not appear to be formed at a greater height than five miles; the lightest of them, the cirri, floating from 3 to 5 miles above the earth. As heat increases capacity for moisture and also rarefies, there is generally an ascending stream of vapor-laden air; and in the hottest part of the day, when evaporation is most rapid, the air at a short

distance from the earth's surface is found to be relatively drier than during the cooler hours, owing to this upward current. Chilled gradually by radiation or suddenly by encountering a cold current or by contact with elevated land, it falls below its dew-point and generates cloud. From inter-tropical seas a column of saturated air continually ascends and does not undergo cooling and condensation until it has reached a considerable elevation. In temperate climates the height necessary to bring about this result is not so considerable and a cumulus often marks the position of the head of the ascending column. Mountains condense watery vapor sometimes by the coldness of their own mass which has radiated rapidly into space, sometimes by deflecting upward a moist current into cooler regions of the atmosphere. In **fog** the particles of water are in a peculiar vesicular condition, imperfectly understood, which retards their aggregation into raindrops. There is strong reason to believe that fogs are unwholesome. Dr. A. Smith found only 20·82 per cent. of oxygen in a dense Manchester fog.

699. Meteorologists have **classified** clouds in three primary divisions—the *cirrus*, the *cumulus* and the *stratus*. Certain simple combinations or modifications of these are the *cirro-cumulus* and *cirro-stratus* ; and the *cumulo-stratus* and *cumulo-cirro-stratus* are compound modifications.

700. The **cirri** are streaks or fibres of cloud, parallel or divergent or forming a fleecy brush or a net-work. They are the highest clouds because the lightest, and reflect the sun's rays after sunset long after lower strata of cloud are dark. They have been known to retain their form unchanged for two days while a strong breeze was blowing lower down, showing that they are raised out of the reach of ordinary atmospheric disturbances. They probably consist of frozen water.

701. The **cumulus** is a hemispherical or conical heap of cloud, like a mountain or a mass of cotton, rising from a horizontal base. After the sun has risen the atmospheric strata in contact with the earth become heated ; so that, their specific gravity being diminished and their capacity for vapor increased, they rise, carrying up with them in solution the vapor which they had absorbed during the night and early morning. Reaching colder regions of the air, the vapor of the ascending current is condensed to cloud ;

which, descending slowly, meets the ascending current and condenses, partially or wholly, its moisture. Thus a mass of cloud continually increasing in size is formed. Were the supply of vapor for condensation equal from all sides the cumulus would be spherical in form; but, as the under surface is in contact with air not fully saturated and, therefore, not yielding condensed vapor, the shape is hemispherical or conical as has been described. The cumulus is formed only by day, then only the conditions necessary for its development being fulfilled. It disappears towards evening; because at that time the upper atmospheric strata have increased in temperature and vapor-absorbing power, while the lower layers are cooler and cease to supply an ascending vapor-bearing current.

702. The **stratus** is a widely-extended, continuous, horizontal sheet of cloud, often forming at sunset, when the air is calm; the atmospheric strata near the earth becoming cooled below the dew-point, and depositing dew on the surface and cloud above. It increases by growth at its upper surface as the higher layers cool. The mists which rise from valleys, lakes &c. during night and early morning, and which are dispersed by the rising sun, belong to this class of cloud.

703. The **cirro-cumulus** consists of small, roundish, fleecy masses, arranged horizontally, close together or in contact. The **cirro-stratus** presents the appearance of horizontal or slightly inclined masses, attenuated towards part or the whole of their circumference, or as thin diffused sheets. It is more compact than the cirrus. In the zenith it looks like a thin bed of cloud; in the horizon like a long, narrow band.

704. The **cumulo-stratus** is a combination of the last with the cumulus. Finally the **cumulo-cirro-stratus** or **nimbus** is a cloud or system of clouds from which rain is actually falling; a horizontal sheet surmounted by cirri, with cumuli beside or below it.

705. When air parts with its moisture in solution at a considerable height from the surface of the earth the minute particles of water of which cloud consists may remain where they were formed or gravitate very slowly downwards. In either case they tend to aggregate into globules; and, when the weight of these is sufficient to

overcome the resistance of the air, they will fall as **rain**. The copious rain which almost invariably accompanies a thunder-storm seems to indicate that the electrical condition of the atmosphere has much to do with the aggregation of the watery particles which produces rain. As the saturation and subsequent chilling of masses of air are the necessary antecedents of the formation of rain, a high temperature with large evaporating surfaces, on the one hand, and a mountain chain or an opposing cold aerial current, on the other, are favorable to copious rain-fall, such as is found in the south-west and north-east of this peninsula.

706. The **Indian rains** depend upon the prevalence of certain winds and are derived from different sources in different parts. The south-west monsoon is a current of saturated air drawn in from the ocean to replace the heated air rising from the plains of Asia. While it prevails it forces up the north-east trade-wind and its influence is felt over the greater part of the peninsula. Striking the western ghats it is chilled and discharges the greater part of its moisture in the copious rains of the western coast, so that it is less moist when it arrives inland, and comparatively dry when it reaches the eastern coast. It blows from the end of May to the beginning or middle of September. As its influence diminishes the north-east trade-wind resumes its course and brings to the eastern side of India the vapor which it has absorbed in its passage over the Bay of Bengal. On one or both of these monsoons the southern and central parts of India depend for their supply of rain.

707. When drops of rain, aggregated in the highest regions of the atmosphere to which vapor rises, are frozen after their formation they constitute **hail**. The force with which they strike the earth shows that they have fallen from a great height; and the electrical condition of the air and vapor is in some way conducive to aggregation at a greater elevation than that at which rain is usually formed.

708. It is not known whether **snow** is formed by the direct conversion of aqueous vapor into ice and the subsequent aggregation of minute particles into flakes; or whether it is frozen cloud.

709. Humidity affects **health** either directly, by diminishing evaporation from skin and lungs; or indirectly,

by increasing temperature. Heat is felt to be more exhausting and continued exertion more difficult when excessive moisture prevents free exhalation of vapor from the body. The capacity for moisture of still air is inversely as the relative humidity and moist hot winds are felt to be oppressive by men and lower animals because evaporation is impeded and bodily temperature rises. The excretion of carbon dioxide from the lungs is greater in a very moist than in a very dry atmosphere. As temperature rises evaporative power rises also and in more rapid ratio; so that heat is better borne than cold when atmospheric humidity is excessive: but either is often tolerated without apparent ill effect beyond discomfort. Individual peculiarities have much influence as regards atmospheric humidity; a dry hot wind, producing copious cutaneous evaporation, being agreeable and apparently salutary to some persons and to others the reverse. In general, the most satisfactory degree of relative humidity seems to lie between 70 and 80 per cent. of saturation.

710. Humidity acts **indirectly** through the power of atmospheric moisture to intercept and absorb heat. Perfectly dry air would transmit almost undiminished both the solar heat and that radiated from the earth; but moist air absorbs and re-radiates in proportion to its degree of absolute humidity. When this is greatest, up to the point of saturation without deposit in the form of cloud, the difference between the indications of the maximum sun and maximum shade thermometers is greatest; because the latter is affected only by terrestrial and aerial radiation while the former absorbs directly the solar heat, and loses, of this, by radiation but little more than it receives by re-radiation from the atmospheric moisture.

711. Humidity appears to have considerable influence upon the prevalence and spread of some **diseases**. *Malarious* affections are worst when the air is nearly saturated with moisture. The spread of *plague* is checked by atmospheric dryness. The same is true of *variola;* and *vaccinia* is propagated with difficulty in dry seasons and climates. *Abdominal* affections prevail most in summer and in proportion to dryness as well as heat. In chronic *pulmonary* diseases a very moist atmosphere is found to be soothing and agreeable; while dry air, producing excessive evaporation from the lungs, irritates them.

712. Coming now to instruments and observations, the rate of **evaporation** is the first point to be ascertained. For this purpose a shallow vessel of uniform horizontal section is supplied with a known quantity of water and exposed to evaporation, protected by a louvred covering from rain and birds. Regular examination, weekly or monthly, will show the diminution of the water and the rate of evaporation from a given surface. A more delicate instrument is the **evaporation-gauge**, a glass tube weighted so as to float vertically in water like a hydrometer, graduated to indicate grains and tenth of grains, and bearing at its upper end a shallow pan. Water is poured into the pan until the zero of the scale coincides with the surface of the water in which the instrument floats. As evaporation from the pan proceeds the tube rises and the scale indicates the amount.

713. In order to find the absolute or relative humidity the **dew-point** has first to be ascertained by observation. The amount of aqueous vapor which air can retain without depositing it as dew or rain, varies, as we have seen, with temperature; and the dew-point at any time is that temperature at which the quantity of vapor then present would be sufficient for saturation, so that any further depression would be attended with deposition of dew. This point is ascertained either by a hygrometer or by the Dry and Wet Bulb Thermometers. There are two hygrometers which may be used, Regnault's and Daniell's, the former giving more accurate results.

714. **Regnault's** hygrometer consists of a glass tube, closed below by a cap of thin and highly polished silver 1·8 inch in depth and 0·8 inch in diameter, a very sensitive thermometer passing through a cork in the upper orifice of the tube and descending nearly to the bottom of the cap. From the same depth rises a thin glass tube, also passing through the cork: while an opening in the upper part of the instrument communicates with an aspirator. When an observation is to be taken, ether is poured into the tube until it is about half full and atmospheric air is drawn through the ether by means of the aspirator and the fine glass tube. As the air bubbles through the ether the temperature of the latter and of the silver cap in contact with it falls until the dew-point is reached, that is, until the air outside the cap is cooled to such a degree that it can no longer retain its moisture, which is deposited as a dew upon the silver. The immersed thermometer indicates the temperature at which this occurs, and it should be read at the instant of the clouding of the silver. Three or four observations are generally necessary to accurate determination, which may be thus made to 0°·1. The temperature of the air must be simultaneously noted.

715. **Daniell's** hygrometer is more portable and convenient than Regnault's, but the indicating thermometer is so small that determinations cannot be made nearer than to 0°·5. There is difficulty also in catching the precise instant at which the dew appears. The instrument consists of two spherical glass bulbs about 1¼ inch in diameter, communicating by a glass tube bent at right angles. One of these is black, the other transparent. A small mercurial thermometer with pyriform bulb is enclosed in that limb of the tube which communicates with the former, the bulb descending to the centre of the black sphere. Sufficient ether to fill this about three-fourths has been introduced, the air excluded as completely as possible by boiling, and the whole hermetically sealed. The other sphere is covered with muslin and the whole supported by a stand on which is fixed a second delicate thermometer indicating the air temperature. To take an observation the ether is first collected into the black sphere and the temperature of the air noted. Ether is then dropped upon the muslin. As it evaporates the cold produced condenses the ether vapor which fills the transparent sphere and the connecting tube and so compels evaporation and consequent cooling in the black sphere. The mercury in the enclosed thermometer falls, and, when it reaches the dew-point, a ring of condensed vapor appears on the black sphere at the level of the surface of the ether within. As the ether recovers its original temperature the ring gradually disappears. At the moment of its disappearance the indication of the enclosed thermometer gives another approximation to the dew-point, and the mean of the two observations is sufficiently near the truth for ordinary purposes.

716. These instruments give the dew-point directly. The **wet and dry bulb** thermometers, by a comparison of their indications, give the same indirectly. These are two similar thermometers, set side by side in a frame, which is fixed four feet from the ground, with the precautions before described (672). One gives the air-temperature in the ordinary way; the other the "temperature of evaporation." The bulb of the latter is covered with muslin which is kept constantly moist by means of cotton thread connecting it with a small reservoir of rain or distilled water fixed on the stand. The cotton should be perfectly free from grease which might interfere with its transmission of water to the bulb. As the moisture evaporates the bulb cools and the mercury falls; and the less the humidity present in the air the more rapid is the evaporation and the greater the depression of the mercury. When the air is nearly saturated evaporation is very slow and the indication of the wet-bulb thermometer is little lower than that of the dry-bulb; at saturation they coincide and their common indication is the dew-point. When the temperature is very low, as when it is freezing, evaporation still proceeds; but very slowly, because the

capacity for moisture is low. The differences are then minute and observations require special care. Unless the air is saturated, the indication of the wet-bulb thermometer will always be below that of the dry-bulb* and above the dew-point.

717. Having observed the difference between the indications of the two thermometers the dew-point is calculated either by **Apjohn's formula**† or by Glaisher's tables. The former, for temperatures of wet-bulb above 32°, is

$$F = f - 0{\cdot}00038\, d\ (p - f)$$

for lower temperatures,

$$F = f - 0{\cdot}00034\, d\ (p - f)$$

where F is the tension of aqueous vapor at the dew-point, which we desire to find; f is the tension at the temperature of evaporation, that indicated by the wet-bulb; d is the difference between the indications and h is the height of the barometrical column.‡

718. It will be observed that this formula gives, not the dew-point itself, but the **tension** of aqueous vapor of the dew-point in terms of the tension at the temperature of evaporation. The corresponding temperatures are obtained from a table, which expresses the tension or elastic force of vapor at various temperatures in inches or

* The greatest difference observed by Mr. Drew at Southampton was 69° — 53° = 16°.

† These formulæ are deduced from Apjohn's, which is ;—

$F = f - \frac{48\ a\ (t - t')}{e} . \frac{p - f}{30}$: when F, f, d and h are as given in the text; a is the specific heat of air; e the latent heat of aqueous vapor; $t - t' = d$; and p, the barometrical pressure in inches. Replacing a and e by their numerical equivalents the formula becomes

$$F = f - 0{\cdot}01147\ (t - t') . \frac{p - f}{30}.$$

‡ In the Bengal Meteorological "Instructions," August's formula is preferred to Apjohn's, as being based on more accurate determinations of elastic force of aqueous vapor and as simplifying calculation by adopting 29·7 as a mean barometrical pressure. The error involved in this assumption is unimportant except at hill-stations, where corrections must be applied. The formula for all temperatures above 32° F. is $F = f - \frac{0{\cdot}48\ (t - t')}{1{,}130 - t'} . 29{\cdot}7$; and for other temperatures $F = f - \frac{0{\cdot}48\ (t - t')}{1240{\cdot}2 - t'} . 29{\cdot}7$. In comparing Meteorological Observations it is necessary to ascertain and bear in mind the formula which has been used.

fractions of an inch of mercury. If a glass tube, closed at one end, whose inner surface has been moistened with water, be filled with mercury and inverted with its open end immersed in a vessel containing mercury, the level in the tube will be lower than in the ordinary barometer; because the upper part of the tube, instead of being a vacuum, is filled with aqueous vapor, whose tension or elastic force depresses the mercury and is measured by the amount of depression. So long as water is present above the mercury, to supply vapor, the tension is constant, however the space may be increased by raising the tube in the vessel, (provided the open end remain immersed); and if the tube be depressed, contracting the space above, some vapor will be re-converted to water and the tension will be the same, temperature and pressure being unchanged. The amount of depression of the mercurial column corresponding to every ordinary degree of temperature has been ascertained and tabulated. It must be added that if air were present, along with the aqueous vapor, the relation of tension to temperature would be unaltered: the only difference between the two cases being that in vacuo the space is saturated instantaneously with vapor, while time is necessary if air be present.

719. The following is the Table necessary for calculating the dew-point by Apjohn's formula :—

Degree of Thermometer.	Inches of Tension.	Degree of Thermometer.	Inches of Tension.	Degree of Thermometer.	Inches of Tension.	Degree of Thermometer.	Inches of Tension.	Degree of Thermometer.	Inches of Tension.	Degree of Thermometer.	Inches of Tension.
1	0·0419	21	0·1076	41	0·2573	61	0·5367	81	1·0572	101	1·9764
2	0·0439	22	0·1128	42	0·2673	62	0·5560	82	1·0921	102	2·0366
3	0·0460	23	0·1183	43	0·2776	63	0·5758	83	1·1280	103	2·0983
4	0·0482	24	0·1240	44	0·2883	64	0·5963	84	1·1650	104	2·1617
5	0·0506	25	0 1300	45	0·2995	65	0·6174	85	1·2031	105	2·2268
6	0·0530	26	0·1363	46	0·3110	66	0·6391	86	1·2421	106	2·2934
7	0·0556	27	0·1429	47	0·3228	67	0·6616	87	1·2822	107	2·3618
8	0·0582	28	0·1498	48	0·3351	68	0·6847	88	1·3236	108	2·4321
9	0·0610	29	0·1571	49	0·3478	69	0·7085	89	1·3660	109	2·5041
10	0·0640	30	0·1647	50	0·3608	70	0·7332	90	1·4098	110	2·5779
11	0·0671	31	0·1727	51	0·3743	71	0·7585	91	1·4547	111	2·6536
12	0·0703	32	0·1811	52	0·3883	72	0·7845	92	1·5007	112	2·7312
13	0·0737	33	0·1884	53	0·4028	73	0·8113	93	1·5481	113	2·8107
14	0·0773	34	0·1960	54	0·4177	74	0·8391	94	1·5967	114	2·8922
15	0·0810	35	0·2039	55	0·4332	75	0·8676	95	1·6467	115	2·9758
16	0·0849	36	0·2121	56	0·4491	76	0·8969	96	1·6981	116	3·0615
17	0·0891	37	0·2205	57	0·4655	77	0·9272	97	1·7509	117	3·1494
18	0·0934	38	0·2292	58	0·4825	78	0·9583	98	1·8051	118	3·2393
19	0·0979	39	0·2382	59	0·5000	79	0·9903	99	1·8607	119	3·3314
20	0·1026	40	0·2476	60	0·5180	80	1·0232	100	1·9178	120	3·4257

720. The calculation of the dew-point by this method will be best explained by an **example.** At a certain hour the barometer stood at 29·802 (p); the dry-bulb thermometer indicated 110°·5, the wet-bulb 74°·5; the difference being 36° (d). The temperature of the wet-bulb being over 32° we use the former of the two formulæ; and, substituting the values just stated for p and d and 0·8533 (tension corresponding to 74°·5, obtained from the Table) for f, we find $F = 0{\cdot}8533 - 0{\cdot}00038 \times 36 \times (29{\cdot}802 - 0{\cdot}8533) = 0{\cdot}4573$. From the Table we find that this tension corresponds to 56°·5, which is, therefore, the dew-point.

721. **Glaisher's factors*** have been deduced from comparisons of observations of the dry and wet-bulb thermometers with the dew-points determined by Daniell's hygrometer. The following formula, with the aid of the Table given below, supplies the dew-point (D), at any hour:—

$$D = t - v\,(t - t');$$

in which t is the dry-bulb and t' the wet-bulb reading, and v the factor corresponding to t in the following Table:—

722. TABLE OF GLAISHER'S FACTORS.

Dry-bulb.	Factor.	Dry-bulb.	Factor.	Dry-bulb.	Factor.	Dry-bulb.	Factor.
21°	7·88	41°	2·26	61°	1·87	81°	1·68
22°	7·60	42°	2·23	62°	1·86	82°	1·67
23°	7·28	43°	2·20	63°	1·85	83°	1·67
24°	6·92	44°	2·18	64°	8·83	84°	1·66
25°	6·53	45°	2·16	65°	1·82	85°	1·65
26°	6·08	46°	2·14	66°	1·81	86°	1·65
27°	5·61	47°	2·12	67°	1·80	87°	1·64
28°	5·12	48°	2·10	68°	1·79	88°	1·64
29°	4·63	49°	2·08	69°	1·78	89°	1·63
30°	4·15	50°	2·06	70°	1·77	90°	1·63
31°	3·70	51°	2·04	71°	1·76	91°	1·62
32°	3·32	42°	2·02	72°	1·75	92°	1·62
33°	3·01	53°	2·00	73°	1·74	93°	1·60
34°	2·77	54°	1·98	74°	1·73	94°	1·60
35°	2·60	55°	1·96	75°	1·72	95°	1·59
36°	2·50	56°	1·94	76°	1·71	96°	1·59
37°	2·42	57°	1·92	77°	1·70	97°	1·59
38°	2·36	58°	1·90	78°	1·69	98°	1·58
39°	2·32	59°	1·89	79°	1·69	99°	1·58
40°	2·29	60°	1·88	80°	1·68	100°	1·57

* These factors assume a constant barometrical pressure and, therefore, cannot give results so accurate as Apjohn's formula.

723. For **example**; suppose the air-temperature (t) to be 80°, the temperature of evaporation (t') 74°. The Table shows the factor (v) corresponding to 80° to be 1·68. Then $D = 80° - 1·68\ (6°) = 80° - 10°·08 = 69°·92$.

724. The **absolute humidity** or total amount of aqueous vapor present in the air at any given time is expressed in grains per cubic foot and is ascertained from the following Table, which gives the quantity of moisture which saturated air contains at different temperatures. The amount present at any moment is that which would be sufficient to saturate at the dew-point. Having determined the dew-point, therefore, we apply to the Table to find the corresponding quantity of moisture.

725. TABLE OF WEIGHT OF VAPOR IN A CUBIC FOOT OF SATURATED AIR, under pressure of 30 inches.*

Temperature.	Grains.	Temperature.	Grains.	Temperature.	Grains.	Temperature.	Grains.
21°	1·4	34°	2·3	47°	3·7	60°	5·8
22°	1·4	35°	2·4	48°	3·8	61°	6·0
23°	1·5	36°	2·5	49°	4·0	62°	6·2
24°	1·5	37°	2·6	50°	4·1	63°	6·4
25°	1·6	38°	2·7	51°	4·2	64°	6·6
26°	1·7	39°	2·8	52°	4·4	65°	6·8
27°	1·8	40°	2·9	53°	4·6	66°	7·0
28°	1·8	41°	3·0	54°	4·7	67°	7·3
29°	1·9	42°	3·1	55°	4·9	68°	7·5
30°	2·0	43°	3·2	56°	5·0	69°	7·8
31°	2·1	44°	3·3	57°	5·2	70°	8·0
32°	2·1	45°	3·4	58°	5·4		
33°	2·2	46°	3·6	59°	5·6		

726. The **relative humidity**, or degree of humidity, is the ratio of the quantity of moisture present in the air at any time to that which would saturate at the actual temperature. It is expressed as per-centage of saturation. It may be calculated from the dew-point and the air-temperature, by means of the table given in (719), being $= F \div f$; that is, the tension of aquous vapor at the dew-

* When the barometer indication differs from 30·000 the weight given by this table must be increased or diminished proportionately.

point divided by that corresponding to the temperature indicated by the dry-bulb thermometer. It is, however, more readily ascertained by means of the following Tables,* which have been calculated for four barometrical pressures, according to Apjohn's formula and Regnault's determinations of tension of aqueous vapor. The Table with pressure nearest to that observed is to be used. The figure at the intersection of the vertical column, headed by the difference between dry and wet-bulbs, with the horizontal line of the reading of the wet-bulb is the relative humidity.

From Mr. Pogson's *Madras Meteorological Reduction Tables.*

727

Table I.—(Barometer at 24 inches.)

Wet. Bulb.	Difference between Dry and Wet Bulbs. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	Wet. Bulb.
31	91	83	76	69	62	56	51	45	40	36	31	27	23	20	16	13	10	8	5	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	31
32	91	84	76	69	62	56	51	45	40	36	31	27	23	20	16	13	10	7	5	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	32
33	92	84	76	69	62	56	51	45	40	36	31	27	23	20	16	13	10	7	4	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	33
34	92	84	77	69	63	57	52	46	41	37	32	28	24	21	17	14	11	9	6	4	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	34
35	92	84	77	70	64	58	53	47	42	38	34	30	26	22	19	16	13	10	8	5	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	35
36	92	85	78	71	65	59	54	48	44	39	35	31	27	24	20	17	15	12	9	7	5	3	1	...	...	...	...	...	...	...	...	...	...	...	...	36
37	92	85	78	72	66	60	55	49	45	40	36	32	29	25	22	19	16	13	11	9	6	4	2	1	...	...	...	...	...	...	...	...	...	...	...	37
38	92	85	79	72	66	61	56	50	46	41	37	33	30	26	23	20	17	15	12	10	8	6	4	2	1	...	...	...	...	...	...	...	...	...	...	38
39	92	86	79	73	67	61	56	51	47	43	39	35	31	28	25	22	19	16	14	12	9	7	5	4	2	1	...	...	...	...	...	...	...	...	...	39
40	93	86	79	73	68	62	57	52	48	44	40	36	32	29	26	23	20	18	15	13	11	9	7	5	4	2	1	...	...	...	...	...	...	...	...	40
41	93	86	80	74	68	63	58	53	49	45	41	37	34	30	27	24	22	19	17	14	12	10	8	7	5	3	2	1	...	...	...	...	...	...	...	41
42	93	86	80	74	69	64	59	54	50	46	42	38	35	31	28	25	23	20	18	16	14	11	10	8	6	5	3	2	1	...	...	...	...	...	...	42
43	93	87	81	75	69	64	59	55	51	47	43	39	36	33	29	26	24	21	19	17	15	13	11	9	8	6	5	3	2	1	...	...	...	...	...	43
44	93	87	81	75	70	65	60	56	51	47	44	40	37	34	31	28	25	23	20	18	16	14	12	10	9	7	6	5	3	2	1	...	...	...	...	44
45	93	87	81	76	71	66	61	56	52	48	45	41	38	35	32	29	26	24	21	19	17	15	13	12	10	9	7	6	5	3	2	1	...	...	...	45
46	94	88	82	76	71	66	61	57	53	49	45	42	39	36	33	30	27	25	23	21	19	17	15	13	11	10	8	7	6	5	3	2	1	...	...	46
47	94	88	82	77	72	67	62	57	54	50	46	43	40	37	34	31	28	26	25	22	20	18	16	14	12	11	10	8	7	6	5	4	3	2	1	47
48	94	88	82	77	72	67	63	59	55	51	47	44	41	38	35	32	30	27	25	23	21	19	17	15	14	12	11	9	8	7	6	5	4	3	2	48
49	94	88	83	77	73	68	63	59	55	52	48	45	42	39	36	33	31	28	26	24	22	20	18	16	15	13	12	10	9	8	7	6	5	4	3	49
50	94	88	83	78	73	68	64	60	56	52	49	45	42	39	36	34	31	29	27	25	23	21	19	17	16	14	13	12	10	9	8	7	6	5	4	50

TABLE I.—(Barometer at 24 inches)—(*Continued*).

Wet Bulb.	Difference between Dry and Wet Bulbs.																																			Wet Bulb.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
51 ...	94	85	83	78	74	69	65	61	57	53	50	46	43	40	37	35	32	30	28	26	24	22	20	18	17	15	14	12	11	10	9	8	7	6	5	... 51
52 ...	94	89	83	79	74	69	65	61	57	54	50	47	44	41	38	36	33	31	29	27	25	23	21	19	18	16	15	13	12	11	10	9	8	7	6	... 52
53 ...	94	89	84	79	74	70	66	62	58	54	51	48	45	42	39	37	34	32	30	28	26	24	22	20	19	17	16	14	13	12	11	10	9	8	7	... 53
54 ...	94	89	84	79	75	70	66	62	59	55	52	49	46	43	40	37	35	33	31	28	27	25	23	21	19	18	17	15	14	13	12	11	10	9	8	... 54
55 ...	95	89	84	79	75	71	67	63	59	56	52	49	46	43	41	38	36	33	31	29	27	26	24	22	20	19	18	16	15	14	13	12	11	10	9	... 55
56 ...	95	89	84	80	75	71	67	63	60	56	53	50	47	44	42	39	37	34	32	30	28	26	25	23	21	20	18	17	16	15	13	12	11	10	9	... 56
57 ...	95	89	85	80	76	71	67	64	60	57	54	50	47	45	42	40	37	35	33	31	29	27	25	24	22	21	19	18	17	15	14	13	12	11	10	... 57
58 ...	95	90	85	80	76	72	68	64	61	57	54	51	48	46	43	40	38	36	34	31	30	28	26	24	23	22	20	19	17	16	15	14	13	12	11	... 58
59 ...	95	90	85	81	76	72	68	65	61	58	55	52	49	46	44	41	39	36	34	32	30	29	27	25	24	22	21	19	18	17	16	15	14	13	12	... 59
60 ...	95	90	85	81	77	73	69	65	62	58	55	52	50	47	44	42	40	37	35	33	31	30	28	26	25	23	22	20	19	18	17	16	15	14	13	... 60
61 ...	95	90	86	81	77	73	69	66	62	59	56	53	50	47	45	43	40	38	36	34	32	30	29	27	25	24	22	21	20	19	17	16	15	14	13	... 61
62 ...	95	90	86	81	77	73	70	66	63	60	57	54	51	48	45	43	41	39	37	35	33	31	29	28	26	25	23	22	21	19	18	17	16	15	14	... 62
63 ...	95	90	86	82	78	74	70	67	63	60	57	54	51	49	46	44	42	39	37	35	33	32	30	28	27	25	24	23	21	20	19	18	17	16	15	... 63
64 ...	95	91	86	82	78	74	70	67	64	61	58	55	52	49	47	44	42	40	38	36	34	32	31	29	27	26	25	23	22	21	20	18	17	16	15	... 64
65 ...	95	91	87	82	78	74	71	67	64	61	58	55	52	50	47	45	43	41	39	37	35	33	31	30	28	27	25	24	23	21	20	19	18	17	16	... 65
66 ...	95	91	87	83	78	75	71	68	64	61	59	56	53	50	48	46	43	41	39	37	35	34	32	31	29	27	26	24	23	22	21	20	19	18	17	... 66
67 ...	95	91	87	83	79	75	71	68	65	62	59	56	53	51	48	46	44	42	40	38	36	34	32	31	29	28	26	25	24	23	21	20	19	18	17	... 67
68 ...	95	91	87	83	79	75	72	68	65	62	59	57	54	51	49	47	44	42	40	38	37	35	33	31	30	28	27	26	24	23	22	21	20	19	18	... 68
69 ...	95	91	87	83	79	76	72	69	66	63	60	57	54	52	49	47	45	43	41	39	37	35	34	32	31	29	28	26	25	24	23	22	20	19	18	... 69
70 ...	96	91	87	83	79	76	72	69	66	63	60	57	55	52	50	48	45	43	41	40	38	36	34	33	31	30	28	27	26	24	23	22	21	20	19	... 70

71	...	96	91	87	83	80	76	73	69	66	64	61	58	55	53	51	49	46	44	42	40	38	36	35	33	32	30	29	28	26	25	24	23	22	21	20	...	71
72	...	96	91	87	84	80	76	73	70	67	64	61	58	56	53	51	49	46	44	42	41	39	37	35	34	32	31	29	28	27	26	24	23	22	21	20	...	72
73	...	96	92	88	84	80	77	73	70	67	64	61	59	56	54	51	49	47	45	43	41	39	37	36	34	33	31	30	29	27	26	25	24	23	22	21	...	73
74	...	96	92	88	84	80	77	74	71	67	65	62	59	57	54	52	50	47	45	43	42	40	38	36	35	33	32	30	29	28	27	25	24	23	22	21	..	74
75	...	96	92	88	84	81	77	74	71	68	65	62	59	57	54	52	50	48	46	44	42	40	38	37	35	34	32	31	30	28	27	26	25	24	23	22	...	75
76	...	96	92	88	84	81	77	74	71	68	65	63	60	57	55	53	50	48	46	44	43	41	39	37	36	34	33	31	30	29	28	27	25	24	23	22	...	76
77	...	96	92	88	84	81	78	74	71	68	66	63	60	58	55	53	51	49	47	45	43	41	40	38	36	35	33	32	31	29	28	27	26	25	24	23	...	77
78	...	96	92	88	85	81	78	75	71	69	66	63	61	58	56	53	51	49	47	45	43	42	40	38	37	35	34	32	31	30	29	28	26	25	24	23	...	78
79	...	96	92	88	85	81	78	75	72	69	66	64	61	58	56	54	52	50	48	46	44	42	40	38	37	36	34	33	32	30	29	28	27	26	25	24	...	79
80	...	96	92	88	85	82	78	75	72	69	66	64	61	59	56	54	52	50	48	46	44	43	41	39	38	36	35	33	32	31	30	28	27	26	25	24	...	80
81	...	96	92	89	85	82	78	75	72	69	67	64	62	59	57	55	53	50	48	46	45	43	41	40	38	37	35	34	32	31	30	29	28	27	26	25	...	81
82	...	96	92	89	85	82	79	76	73	70	67	64	62	59	57	55	53	51	49	47	45	43	42	40	39	37	36	34	33	32	30	29	28	27	26	25	...	82
83	...	96	92	89	85	82	79	76	73	70	67	65	62	60	57	55	53	51	49	47	46	44	42	41	39	37	36	35	33	32	31	30	29	28	27	26	...	83
84	...	96	92	89	85	82	79	76	73	71	68	65	62	60	58	56	54	52	50	48	46	44	42	41	39	38	36	35	34	32	31	30	29	28	27	26	...	84
85	...	96	92	89	86	82	79	76	73	71	68	65	63	60	58	56	54	52	50	48	46	45	43	41	40	38	37	35	34	33	32	31	29	28	27	26	...	85
86	...	96	92	89	86	83	79	76	73	71	68	66	63	61	59	56	54	52	50	48	47	45	43	42	40	39	37	36	35	33	32	31	30	29	28	27	.	86
87	..	96	93	89	86	83	80	77	74	71	68	66	63	61	59	57	55	53	51	49	47	45	44	42	40	39	38	36	35	34	33	31	30	29	28	27	...	87
88	...	96	93	89	86	83	80	77	74	71	68	66	64	61	59	57	55	53	51	49	47	46	44	43	41	39	38	37	35	34	33	32	31	29	28	27	...	88
89	...	96	93	89	86	83	80	77	74	71	69	66	64	62	59	57	55	53	51	50	48	46	44	43	41	40	38	37	36	34	33	32	31	30	29	28	...	89
90	...	96	93	89	86	83	80	77	74	72	69	67	64	62	60	58	56	54	52	50	48	46	45	43	42	40	39	38	36	35	34	33	31	30	29	28	...	90

TABLE II.—(Barometer at 26 inches).

Wet Bulb.	Difference between Dry and Wet Bulbs.																																		Wet Bulb.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
36 ...	92	84	77	70	63	56	52	46	41	37	32	28	24	21	17	14	11	9	6	4	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	... 36
37 ...	92	84	77	71	64	58	53	47	43	38	34	30	26	22	19	16	13	10	8	5	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	... 37
38 ...	92	85	78	71	65	59	54	49	44	39	35	31	27	24	21	17	14	12	9	7	5	3	1	...	...	...	...	...	...	...	...	...	...	...	...	... 38
39 ...	92	85	78	72	66	60	55	50	45	40	36	32	29	25	22	19	16	13	11	9	6	4	2	1	...	...	...	...	...	...	...	...	...	...	...	... 39
40 ...	92	85	79	72	66	61	56	51	46	41	37	34	30	27	23	20	17	15	12	10	8	6	4	2	...	...	...	...	...	...	...	...	...	...	...	.. 40
41 ...	92	86	79	73	67	62	56	51	47	43	39	35	31	28	25	22	19	16	14	12	9	7	5	4	2	...	...	...	...	...	...	...	...	...	...	... 41
42 ...	93	86	79	73	68	62	57	52	48	44	40	36	32	29	26	23	20	18	15	13	11	9	7	5	3	2	...	...	...	...	...	...	...	...	...	... 42
43 ...	93	86	80	74	68	63	58	53	49	45	41	37	34	30	27	24	22	19	17	14	12	10	8	7	5	3	2	1	...	...	...	...	...	...	...	... 43
44 ...	93	86	80	74	69	64	59	54	50	46	42	38	35	31	28	25	23	20	18	16	14	11	10	8	7	5	4	2	1	...	...	...	...	...	...	... 44
45 ...	93	87	81	75	70	64	59	55	51	47	43	39	36	33	29	27	24	21	19	17	15	13	11	9	8	6	5	3	2	1	...	...	...	...	...	... 45
46 ...	93	87	81	75	70	65	60	56	52	48	44	40	37	34	31	28	25	23	20	18	16	14	12	10	9	7	6	5	3	2	1	...	...	...	...	... 46
47 ..	93	87	81	76	71	66	61	57	52	48	45	41	38	35	32	29	26	24	22	19	17	15	13	12	10	9	7	6	4	3	2	1	...	...	...	... 47
48 ...	94	87	82	76	71	66	62	57	53	49	46	42	39	36	33	30	27	25	23	20	18	16	15	13	11	10	8	7	6	4	3	2	1	...	...	... 48
49 ...	94	88	82	77	72	67	62	58	54	50	46	43	40	37	34	31	28	26	24	22	20	18	16	14	13	11	9	8	7	6	4	3	2	1	1	... 49
50 ...	94	88	82	77	72	67	63	59	55	51	47	44	41	38	35	32	29	27	25	23	21	19	17	15	14	12	11	9	8	7	6	5	4	3	2	.. 50
51 ...	94	88	83	78	73	68	63	59	55	52	48	45	42	39	36	33	30	28	26	24	22	20	18	16	15	13	12	10	9	8	7	6	5	4	3	... 51
52 ...	94	88	83	78	73	68	64	60	56	52	49	46	42	39	37	34	31	29	27	25	23	21	19	17	16	14	13	11	10	9	8	7	6	5	4	... 52
53 ...	94	89	83	78	73	69	65	61	57	53	50	47	43	40	38	35	32	30	28	26	24	22	20	18	17	15	14	12	11	10	9	8	7	6	5	... 53
54 ...	94	89	83	79	74	69	65	61	57	54	50	47	44	41	38	36	33	31	29	27	25	23	21	19	18	16	15	13	12	11	10	9	8	7	6	... 54
55 ...	94	89	84	79	74	70	66	62	58	54	51	48	45	42	39	37	34	32	30	28	26	24	22	20	19	17	16	14	13	11	11	10	9	8	7	... 55

56	...	94	89	84	79	75	70	66	62	59	55	52	49	46	43	40	37	35	33	31	28	26	25	23	21	20	18	17	15	14	13	12	11	10	9	8	...	56
57	...	95	89	84	79	75	71	67	63	59	56	52	49	46	44	41	38	36	33	31	29	27	25	24	22	20	19	17	16	15	13	12	11	10	9	9	...	57
58	...	95	89	85	80	75	71	67	63	60	56	53	50	47	44	42	39	37	34	32	30	28	26	25	23	21	20	18	17	16	14	13	12	11	10	9	...	58
59	...	95	90	85	80	76	72	68	64	60	57	54	51	48	45	42	40	37	35	33	31	29	27	26	24	22	21	19	18	17	15	14	13	12	11	10	...	59
60	..	95	90	85	80	76	72	68	64	61	57	54	51	48	46	43	41	38	36	34	32	30	28	26	25	23	22	20	19	17	16	15	14	13	12	11	...	60
61	...	95	90	85	81	76	72	69	65	61	58	55	52	49	46	44	41	39	37	34	32	31	29	27	25	24	22	21	20	18	17	16	15	14	13	12	...	61
62	...	95	90	85	81	77	73	69	65	62	59	55	52	50	47	44	42	39	37	35	33	31	29	28	26	25	23	22	20	19	18	17	15	14	13	12	...	62
63	...	95	90	86	81	77	73	69	66	62	59	56	53	50	47	45	43	40	38	36	34	32	30	28	27	25	24	22	21	20	19	17	16	15	14	13	...	63
64	...	95	90	86	81	77	73	70	66	63	60	57	54	51	48	46	43	41	39	37	35	33	31	29	28	26	24	23	22	20	19	18	17	16	15	14	...	64
65	...	95	90	86	82	78	74	70	67	63	60	57	54	51	49	46	44	41	39	37	35	33	32	30	28	27	25	24	22	21	20	19	18	17	16	15	...	65
66	..	95	91	86	82	78	74	70	67	64	60	58	55	52	49	47	44	42	40	38	36	34	32	31	29	27	26	24	23	22	21	20	19	17	16	15	..	66
67	...	95	91	86	82	78	74	71	67	64	61	58	55	52	50	47	45	42	41	39	37	35	33	31	30	28	26	25	24	23	21	20	19	18	17	16	...	67
68	...	95	91	87	82	78	75	71	68	64	61	58	56	53	50	48	46	43	41	39	37	35	34	32	30	29	27	25	24	23	22	21	20	19	18	17	...	68
69	...	95	91	87	83	79	75	71	68	65	62	59	56	54	51	48	46	43	42	40	38	36	34	32	31	29	27	26	25	24	22	21	20	19	18	17	...	69
70	...	95	91	87	83	79	75	72	69	65	62	59	57	54	51	49	47	44	42	40	38	37	35	33	31	30	28	27	26	24	23	22	21	20	19	18	...	70
71	...	96	91	87	83	79	76	72	69	66	63	60	57	54	52	50	47	44	43	41	39	37	35	34	32	31	28	28	26	25	24	23	22	20	19	18	...	71
72	...	96	91	87	83	79	76	73	69	66	63	60	58	55	52	50	48	45	43	41	40	38	36	34	33	31	29	28	27	25	24	23	22	21	20	19	...	72
73	...	96	91	87	83	80	76	73	70	67	64	61	58	55	53	50	48	46	44	42	40	38	36	35	33	32	30	29	28	26	25	24	23	22	21	20	...	73
74	...	96	91	88	84	80	76	73	70	67	64	61	58	56	53	51	49	46	45	43	41	38	37	35	34	32	30	29	28	27	26	24	23	22	21	20	...	74
75	...	96	92	88	84	80	77	73	70	67	64	62	59	56	54	51	49	47	45	43	41	39	38	36	34	33	31	30	29	27	26	25	24	23	22	21	...	75
76	...	96	92	88	84	80	77	74	70	67	65	62	59	57	54	52	50	47	46	44	42	40	38	36	35	33	31	30	29	28	27	26	24	23	22	21	...	76
77	...	96	92	88	84	81	77	74	71	68	65	62	60	57	55	52	50	48	46	44	42	40	39	37	35	34	32	31	30	28	27	26	25	24	23	22	...	77
78	...	96	92	88	84	81	78	74	71	68	65	63	60	57	55	53	51	48	46	44	43	41	39	37	36	34	32	32	30	29	28	27	25	24	23	22	...	78
79	...	96	92	88	84	81	78	74	71	68	66	63	60	58	55	53	51	48	47	45	43	41	40	38	36	35	33	32	31	29	28	27	26	25	24	23	...	79
80	...	96	92	88	85	81	78	75	72	69	66	63	61	58	56	54	51	49	47	45	43	42	40	38	37	35	33	32	31	30	29	28	26	25	24	23	...	80

TABLE II.—(Barometer at 26 inches)—(*Continued*).

Wet Bulb.	Difference between Dry and Wet Bulbs.																																			Wet Bulb.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
81 ...	96	92	88	85	81	78	75	72	69	66	64	61	58	56	54	52	50	48	46	44	42	40	39	37	36	34	33	32	30	29	28	27	26	25	24	... 81
82 ...	66	92	88	85	82	78	75	72	69	67	64	61	59	56	54	52	50	48	46	44	43	41	39	38	36	35	33	32	31	30	28	27	26	25	24	... 82
83 ...	96	92	88	85	82	78	75	72	70	67	64	62	59	57	55	53	51	49	47	45	43	41	40	38	37	35	34	33	31	30	29	28	27	26	25	... 83
84 ...	96	92	89	85	82	79	76	73	70	67	64	62	60	57	55	53	51	49	47	45	43	42	40	39	37	36	34	33	32	31	29	28	27	26	25	... 84
85 ...	96	92	89	85	82	79	76	73	70	67	65	62	60	58	55	53	51	49	47	46	44	42	41	39	38	36	35	33	32	31	30	29	28	27	26	... 85
86 ...	96	92	89	85	82	79	76	73	70	68	65	62	60	58	56	54	52	50	48	46	44	43	41	39	38	36	35	34	33	31	30	29	28	27	26	... 86
87 ...	96	92	89	86	82	79	76	73	71	67	65	63	61	58	56	54	52	50	48	46	45	43	41	40	38	37	36	34	33	32	31	30	28	27	26	... 87
88 ...	96	93	89	86	83	79	76	74	71	67	66	63	61	59	56	54	52	50	49	47	45	43	42	40	39	37	36	35	33	32	31	30	29	28	27	... 88
89 ...	96	93	89	86	83	80	77	74	71	67	66	63	61	59	57	55	53	51	49	47	45	44	42	41	39	38	36	35	34	33	31	30	29	28	27	... 89
90 ...	96	93	89	86	83	80	77	74	71	69	66	64	61	69	57	55	53	51	49	48	46	44	43	41	40	38	37	35	34	33	32	31	30	29	28	... 90
91 ...	96	93	89	86	83	80	77	74	71	69	66	64	62	59	57	55	53	51	50	48	46	45	43	41	40	39	37	36	35	33	32	31	30	29	28	... 91
92 ...	96	93	90	86	83	80	77	74	72	69	67	64	62	60	58	56	54	52	50	48	46	45	43	42	40	39	38	36	35	34	33	31	30	29	28	... 92
93 ...	96	93	90	86	83	80	77	75	72	69	67	65	62	60	58	56	54	52	50	49	47	45	44	42	41	39	38	37	35	34	33	32	31	30	29	... 93
94 ...	96	93	90	86	83	80	78	75	72	70	67	65	62	60	58	56	54	52	51	49	47	46	44	42	41	40	38	37	36	35	33	32	31	30	29	... 94
95 ...	96	93	90	87	84	81	78	75	72	70	67	65	63	61	59	57	55	53	51	49	47	46	44	43	41	40	39	37	36	35	34	33	32	31	30	... 95

TABLE III.—(Barometer at 28 inches).

Wet Bulb.	Difference between Dry and Wet Bulbs.																																		Wet Bulb.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
41 ...	92	85	78	72	66	60	55	50	45	41	36	32	28	25	22	19	16	13	11	9	7	5	4	2	1	...	...	...	...	...	...	...	...	...	...	... 41
42 ...	92	85	79	72	67	61	56	51	46	42	38	34	30	27	23	20	18	15	13	10	8	6	5	2	1	...	...	...	...	...	...	...	...	...	...	... 42
43 ...	93	86	79	73	67	62	56	52	47	43	39	35	31	28	25	22	19	16	14	12	10	7	6	4	2	1	...	...	...	...	...	...	...	...	...	... 43
44 ...	93	86	80	74	68	62	57	53	48	44	40	36	33	29	26	23	20	18	15	13	11	9	7	5	3	2	1	...	...	...	...	...	...	...	...	... 44
45 ...	93	86	80	74	68	63	58	53	49	45	41	37	34	30	27	24	22	19	17	14	12	10	8	7	5	3	2	1	...	...	...	...	...	...	...	... 45
46 ...	93	86	80	75	69	64	59	54	50	46	42	38	35	32	29	26	23	20	18	16	14	12	10	8	6	5	3	2	1	...	...	...	...	...	...	... 46
47 ...	93	87	81	75	70	64	60	55	51	47	43	39	36	33	30	27	24	22	19	17	15	13	11	9	7	6	5	3	2	1	...	...	...	...	...	... 47
48 ...	93	87	81	75	70	65	60	56	52	48	44	40	37	34	31	28	25	23	20	18	16	14	12	11	9	7	6	5	3	2	1	...	...	...	...	... 48
49 ...	94	87	81	76	71	66	61	57	52	49	45	41	38	35	32	29	26	24	22	19	17	15	13	12	10	9	7	6	5	3	2	1	...	...	...	... 49
50 ...	94	88	82	76	71	66	62	57	53	49	46	42	39	36	33	30	28	25	23	21	18	16	15	13	11	10	8	7	5	4	3	2	1	...	...	... 50
51 ...	94	88	82	77	72	67	62	58	54	50	47	43	40	37	34	31	29	26	24	22	20	18	16	14	13	11	10	8	7	6	5	4	3	2	1	... 51
52 ...	94	88	82	77	72	67	63	59	55	51	47	44	41	38	35	32	30	27	25	23	21	19	17	15	14	12	11	9	8	7	6	5	4	3	2	... 52
53 ...	94	88	83	78	73	68	64	59	56	52	48	45	42	39	36	33	31	28	26	24	22	20	18	16	15	13	12	10	9	8	7	6	5	4	3	... 53
54 ...	94	88	83	78	73	69	64	60	56	52	49	46	43	40	37	34	32	29	27	25	23	21	19	17	16	14	13	11	10	9	8	7	6	5	4	... 54
55 ...	94	89	83	78	74	69	65	61	57	53	50	46	43	40	38	35	32	30	28	26	24	22	20	18	17	15	14	12	11	10	9	8	7	6	5	... 55
56 ...	94	89	84	79	74	70	65	61	57	54	50	47	44	41	39	36	33	31	29	27	25	23	21	19	18	16	15	13	12	11	10	9	8	7	6	... 56
57 ...	94	89	84	79	74	70	66	62	58	54	51	48	45	42	39	37	34	32	30	28	26	24	22	20	19	17	16	14	13	12	11	10	9	8	7	... 57
58 ...	94	89	84	79	75	70	66	62	59	55	52	49	46	43	40	38	35	33	31	29	27	25	23	21	20	18	17	15	14	13	11	10	9	9	8	.. 58
59 ...	95	89	84	80	75	71	67	63	59	56	53	49	46	44	41	38	36	34	31	29	27	26	24	22	21	19	18	16	15	14	12	11	10	9	8	... 59
60 ...	95	89	85	80	75	71	67	63	60	56	53	50	47	44	42	39	37	34	32	30	28	26	25	23	21	20	19	17	16	15	13	12	11	10	9	... 60

Table III.—(Barometer at 28 inches)—(*Continued*).

Wet Bulb.	Difference between Dry and Wet Bulbs.																																			Wet. Bulb.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
61	95	90	85	80	76	72	68	64	60	57	54	51	48	45	42	40	37	35	33	31	29	27	25	24	22	21	19	18	17	15	14	13	12	11	10	61
62	95	90	85	80	76	72	68	64	61	58	54	51	48	46	43	41	38	36	34	32	30	28	26	25	23	22	20	19	17	16	15	14	13	12	11	62
63	95	90	85	81	76	72	69	65	62	58	55	52	49	46	44	41	39	37	35	33	31	29	27	25	24	22	21	20	18	17	16	15	14	13	12	63
64	95	90	85	81	77	73	69	65	62	59	56	53	50	47	44	42	40	37	35	33	31	30	28	26	25	23	22	20	19	18	17	16	15	14	13	64
65	95	90	86	81	77	73	69	66	62	59	56	53	50	48	45	43	40	38	36	34	32	30	29	27	25	24	22	21	20	19	17	16	15	14	13	65
66	95	90	86	82	77	74	70	66	63	60	57	54	51	48	46	43	41	39	37	35	33	31	29	28	26	25	23	22	21	19	18	17	16	15	14	66
67	95	90	86	82	78	74	70	67	63	60	57	54	51	49	46	44	42	39	37	35	33	32	30	28	27	25	24	23	21	20	19	18	17	16	15	67
68	95	91	86	82	78	74	71	67	64	61	58	55	52	49	47	45	42	40	38	36	34	32	31	29	27	26	25	23	22	21	19	18	17	16	15	68
69	95	91	86	82	78	75	71	67	64	61	58	55	53	50	48	45	43	41	39	37	35	33	31	30	28	27	25	24	23	21	20	19	18	17	16	69
70	95	91	87	82	79	75	71	68	65	62	59	56	53	51	48	46	43	41	39	37	35	34	32	30	29	27	26	25	23	22	21	20	19	18	17	70
71	95	91	87	83	79	75	72	68	65	62	59	56	54	51	49	46	44	42	40	38	36	34	33	31	29	28	27	25	24	23	21	20	19	18	17	71
72	95	91	87	83	79	75	72	69	65	62	59	57	54	51	49	47	45	42	40	39	37	35	33	32	30	29	27	26	25	23	22	21	20	19	18	72
73	95	91	87	83	79	76	72	69	66	63	60	57	55	52	50	47	45	43	41	39	37	35	34	32	31	29	28	26	25	24	23	22	21	20	19	73
74	95	91	87	83	80	76	73	69	66	63	60	58	55	52	50	48	46	44	42	40	38	36	34	33	31	30	28	27	26	24	23	22	21	20	19	74
75	96	91	87	83	80	76	73	70	67	64	61	58	55	53	51	48	46	44	42	40	38	37	35	33	32	30	29	28	26	25	24	23	22	21	20	75
76	96	92	87	84	80	77	73	70	67	64	61	58	56	53	51	49	47	15	43	41	39	37	35	34	32	31	30	28	27	26	25	23	22	21	20	76
77	96	92	88	84	80	77	73	70	67	64	62	59	56	54	52	49	47	45	43	41	40	38	36	34	33	31	30	29	27	26	25	24	23	22	21	77
78	96	92	88	84	80	77	74	71	68	65	62	59	57	54	52	50	48	46	44	42	40	38	37	35	34	32	31	30	28	27	26	24	23	22	21	78
79	96	92	88	84	81	77	74	71	68	65	62	60	57	55	52	50	48	46	44	42	40	39	37	36	34	33	31	30	29	27	26	25	24	23	22	79
80	96	92	88	84	81	78	74	71	68	65	63	60	57	55	53	51	48	47	45	43	41	39	38	36	35	33	32	30	29	28	27	26	24	23	22	80

81	...	96	92	88	85	81	78	75	71	69	66	63	60	58	55	53	51	49	47	45	43	41	40	38	36	35	33	32	31	29	28	27	26	25	24	23	...	81
82	...	96	92	88	85	81	78	75	72	69	66	63	61	58	56	54	52	49	47	45	44	42	40	39	37	35	34	33	31	30	29	28	26	25	24	23	...	82
83	...	96	92	88	85	81	78	75	72	69	66	64	61	59	56	54	52	50	48	46	44	42	41	39	37	36	34	33	32	30	29	28	27	26	25	24	...	83
84	...	96	92	89	85	82	78	75	72	69	67	64	61	59	57	54	52	50	48	46	45	43	41	39	38	36	35	34	32	31	30	29	27	26	25	24	...	84
85	...	96	92	89	85	82	79	75	73	70	67	64	62	59	57	55	53	51	49	47	45	43	42	40	38	37	35	34	33	31	30	29	28	27	26	25	...	85
86	...	96	92	89	85	82	79	76	73	70	67	65	62	60	57	55	53	51	49	47	45	14	42	40	39	37	36	34	33	32	31	30	28	27	26	25	...	86
87	...	96	92	89	85	82	79	76	73	70	67	65	62	60	58	56	53	51	49	47	46	14	42	41	39	38	36	35	34	32	31	30	29	28	27	26	...	87
88	...	96	92	89	86	82	79	76	73	70	68	65	63	60	58	56	54	52	50	18	46	44	43	41	40	38	37	35	34	33	31	30	29	28	27	26	...	88
89	...	96	93	89	86	82	79	76	73	71	68	65	63	61	58	56	54	52	50	18	47	45	43	42	40	39	37	36	34	33	32	31	30	29	28	27	...	89
90	...	96	93	89	86	83	80	77	74	71	68	66	63	61	59	57	54	52	50	49	47	45	44	42	40	39	37	36	35	34	32	31	30	29	28	27	...	90
91	...	96	93	89	86	83	80	77	74	71	69	66	64	61	59	57	55	53	51	49	47	46	44	42	41	39	38	37	35	34	33	32	30	29	28	27	...	91
92	...	96	93	89	86	83	80	77	74	71	69	66	64	62	59	57	55	53	51	49	48	46	44	43	41	40	38	37	36	34	33	32	31	30	29	28	...	92
93	...	96	93	89	86	83	80	77	74	72	69	67	64	62	60	58	55	53	52	50	48	46	45	43	42	40	39	37	36	35	34	32	31	30	29	28	..	93
94	...	96	93	89	86	83	80	77	75	72	69	67	64	62	60	58	56	54	52	50	48	47	45	43	42	40	39	38	36	35	34	33	32	31	29	28	...	94
95	...	96	93	90	86	83	80	78	75	72	69	67	65	62	60	58	56	54	52	50	49	47	45	44	42	41	39	38	37	36	34	33	32	31	30	29	...	95
96	...	96	93	90	87	83	80	78	75	72	70	67	65	63	60	58	56	54	53	51	49	47	46	44	43	41	40	38	37	36	35	34	32	31	30	29	...	96
97	...	96	93	90	87	84	81	78	75	72	70	67	65	63	61	59	57	55	53	51	49	48	46	44	43	41	40	39	37	36	35	34	33	32	31	30	...	97
98	...	96	93	90	87	84	81	78	75	73	70	68	65	63	61	59	57	55	53	51	50	48	46	45	43	42	40	39	38	37	35	34	33	32	31	30	...	98
99	..	97	93	90	87	84	81	78	75	73	70	68	66	63	61	69	57	55	53	52	50	48	47	45	44	42	41	39	38	37	36	34	33	32	31	30	...	99
100	...	97	93	90	87	84	81	78	76	73	71	68	66	64	62	60	58	56	54	52	50	49	47	45	44	13	41	40	38	37	36	35	34	33	32	31	...	100

TABLE IV.—(Barometer at 30 inches).

Wet Bulb.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	Wet Bulb.
	Difference between Dry and Wet Bulbs.																																			
41 ...	92	84	77	71	65	59	53	48	43	39	34	30	26	23	20	16	14	11	8	6	4	2	...	...	...	...	...	...	...	...	...	...	...	...	...	... 41
42 ...	92	85	78	72	65	60	54	49	44	40	36	32	28	24	21	18	15	12	10	8	5	3	1	...	...	...	...	...	...	...	...	...	...	...	...	... 42
43 ...	92	85	78	72	66	60	55	50	45	41	37	33	29	26	22	19	17	14	11	9	7	5	3	1	...	...	...	...	...	...	...	...	...	...	...	... 43
44 ...	93	85	79	73	67	61	56	51	46	42	38	34	30	27	24	21	18	15	13	11	8	6	4	3	1	...	...	...	...	...	...	...	...	...	...	... 44
45 ...	93	86	79	73	67	62	57	52	47	43	39	35	32	28	25	22	19	17	14	12	10	8	6	4	2	1	...	...	...	...	...	...	...	...	...	... 45
46 ...	93	86	80	74	68	63	58	53	48	44	40	36	33	30	26	24	21	18	16	13	11	9	7	5	4	2	1	...	...	...	...	...	...	...	...	... 46
47 ...	93	86	80	74	69	63	58	54	49	45	41	38	34	31	28	25	22	19	17	15	13	11	9	7	5	4	2	1	...	...	...	...	...	...	...	... 47
48 ...	93	87	81	75	69	64	59	55	50	46	42	39	35	32	29	26	23	21	18	16	14	12	10	8	7	5	4	2	1	...	...	...	...	...	...	... 48
49 ...	93	87	81	75	70	65	60	55	51	47	43	40	36	33	30	27	25	22	20	17	15	13	11	10	8	6	5	4	2	1	...	...	...	...	...	... 49
50 ...	93	87	81	76	70	65	61	56	52	48	44	41	37	34	31	28	26	23	21	19	16	14	13	11	9	8	6	5	3	2	1	...	...	...	...	... 50
51 ...	94	87	82	76	71	66	61	57	53	49	45	42	38	35	32	29	27	24	22	20	18	16	14	12	10	9	7	6	5	3	2	1	...	...	...	... 51
52 ...	94	88	82	77	71	67	62	58	54	50	46	43	39	36	33	30	28	25	23	21	19	17	15	13	12	10	9	7	6	5	4	2	1	1	...	... 52
53 ...	94	88	82	77	72	67	63	58	54	50	47	43	40	37	34	31	29	26	24	22	20	18	16	14	13	11	10	8	7	6	5	4	3	2	1	... 53
54 ...	94	88	83	77	72	68	63	59	55	51	48	44	41	38	35	32	30	27	25	23	21	19	17	15	14	12	11	10	8	7	6	5	4	3	2	... 54
55 ...	94	88	83	78	73	68	64	60	56	52	48	45	42	39	36	33	31	28	26	24	22	20	18	17	15	13	12	11	9	8	7	6	5	4	3	... 55
56 ...	94	88	83	78	73	69	64	60	56	53	49	46	43	40	37	34	32	29	27	25	23	21	19	17	16	14	13	12	10	9	8	7	6	5	4	... 56
57 ...	94	89	83	78	74	69	65	61	57	53	50	47	44	41	38	35	33	30	28	26	24	22	20	18	17	15	14	13	11	10	9	8	7	6	5	... 57
58 ...	94	89	84	79	74	70	66	62	58	54	51	47	44	42	39	36	34	31	29	27	25	23	21	19	18	16	15	14	12	11	10	9	8	7	6	... 58
59 ...	94	89	84	79	74	70	66	62	58	55	51	48	45	42	39	37	34	32	30	28	26	24	22	20	19	17	16	14	13	12	11	10	9	8	7	... 59
60 ...	94	89	84	79	75	71	67	63	59	55	52	49	46	43	40	38	35	33	31	29	27	25	23	21	20	18	17	15	14	13	12	11	10	9	8	... 60

61	...	95	89	84	80	75	71	67	63	60	56	53	50	47	44	41	39	36	34	32	30	28	26	24	22	21	19	18	16	15	14	13	12	11	9	9	...	61
62	...	95	90	85	80	76	71	67	64	60	57	53	50	47	45	42	39	37	35	32	30	28	27	25	23	22	20	19	17	16	15	14	12	11	10	9	...	62
63	...	95	90	85	80	76	72	68	64	61	57	54	51	48	45	43	40	38	35	33	31	29	27	26	25	22	21	20	18	17	16	14	13	12	11	10	...	63
64	...	95	90	85	81	76	72	68	65	61	58	55	52	49	46	43	41	38	36	34	32	30	28	26	25	23	22	20	19	18	16	15	14	13	12	11	...	64
65	...	95	90	85	81	77	73	69	65	62	58	55	52	49	47	44	41	39	37	35	33	31	29	27	26	24	23	21	20	18	17	16	15	14	13	12	...	65
66	...	95	90	85	81	77	73	69	66	62	59	56	53	50	47	45	42	40	38	36	34	32	30	28	26	25	23	22	21	19	18	17	16	15	14	13	...	66
67	...	95	90	86	81	77	73	69	66	63	59	56	53	50	48	45	43	41	38	36	34	32	30	29	27	25	24	23	21	20	19	18	16	15	14	13	...	67
68	...	95	90	86	82	78	74	70	66	63	60	57	54	51	48	46	44	41	39	37	35	33	31	29	28	26	25	23	22	21	19	18	17	16	15	14	...	68
69	...	95	90	86	82	78	74	70	67	63	60	57	54	52	49	46	44	42	40	38	36	34	32	30	28	27	25	24	23	21	20	19	18	17	16	15	...	69
70	...	95	91	86	82	78	74	71	67	64	61	58	55	52	50	47	45	42	40	38	36	34	33	31	29	28	26	25	23	22	21	20	18	17	16	15	...	70
71	...	95	91	86	82	78	75	71	68	64	61	58	55	53	50	48	45	43	41	39	37	35	33	31	30	28	27	25	24	23	21	20	19	18	17	16	..	71
72	...	95	91	87	82	79	75	71	68	65	62	59	56	53	51	48	46	44	42	39	37	36	34	32	30	29	27	26	25	23	22	21	20	19	18	17	...	72
73	...	95	91	87	83	79	75	72	68	65	62	59	56	54	51	49	46	44	42	40	38	36	34	33	31	30	28	27	25	24	23	22	20	19	18	17	...	73
74	...	95	91	87	83	79	76	72	69	66	62	60	57	54	52	49	47	45	43	41	39	37	35	33	32	30	29	27	26	25	23	22	21	20	19	18	...	74
75	...	95	91	87	83	79	76	72	69	66	63	60	57	55	52	50	47	45	43	41	39	37	36	34	32	31	29	28	27	25	24	23	22	21	20	19	...	75
76	...	96	91	87	83	80	76	73	69	66	63	60	58	55	53	50	48	46	44	42	40	38	36	34	33	31	30	29	27	26	25	23	22	21	20	19	..	76
77	...	96	91	87	83	80	76	73	70	67	64	61	58	56	53	51	48	46	44	42	40	39	37	35	33	32	30	29	28	26	25	24	23	22	21	20	...	77
78	...	96	91	87	84	80	77	73	70	67	64	61	59	56	54	51	49	47	45	43	41	39	37	36	34	33	31	30	28	27	26	25	24	22	21	20	...	78
79	...	96	92	88	84	80	77	74	70	67	65	62	59	56	54	52	49	47	45	43	41	40	38	36	35	33	32	30	29	28	26	25	24	23	22	21	...	79
80	...	96	92	88	84	81	77	74	71	68	65	62	59	57	54	52	50	48	46	44	42	40	38	37	35	34	32	31	29	28	27	26	25	23	22	21	...	80
81	...	96	92	88	84	81	77	74	71	68	65	62	60	57	55	53	50	48	46	44	42	41	39	37	36	34	33	31	30	29	27	26	25	24	23	22	...	81
82	..	96	92	88	84	81	78	74	71	68	66	63	60	58	55	53	51	49	47	45	43	41	39	38	36	35	33	32	30	29	28	27	26	25	24	23	..	82
83	...	96	92	88	85	81	78	75	72	69	66	63	60	58	56	53	51	49	47	45	43	42	40	38	37	35	34	32	31	30	28	27	26	25	24	23	...	83
84	..	96	92	88	85	82	78	75	72	69	66	63	61	58	56	54	52	50	48	46	44	42	40	39	37	36	34	33	31	30	29	28	27	26	25	24	...	84
85	...	96	92	88	85	82	78	75	72	69	66	64	61	59	56	54	52	50	48	46	44	42	41	39	38	36	35	33	32	31	29	28	27	26	25	24	...	85

TABLE IV.—(Barometer at 30 inches)—(*Continued*).

Wet Bulb.		Difference between Dry and Wet Bulbs.																																			Wet Bulb.
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35		
86	...	96	92	89	85	82	78	75	72	70	67	64	61	59	57	55	52	50	48	46	45	43	41	40	38	37	35	34	32	31	30	29	28	26	25	24	...	86
87	...	96	92	89	85	82	79	76	73	70	67	64	62	60	57	55	53	51	49	47	45	43	42	40	38	37	36	34	33	32	30	29	28	27	26	25	...	87
88	...	96	92	89	85	82	79	76	73	70	68	65	62	60	58	55	53	51	49	47	46	44	42	41	39	37	36	35	33	32	31	30	28	27	26	25	...	88
89	...	96	92	89	86	82	79	76	73	70	68	65	63	60	58	56	54	52	50	48	46	44	43	41	39	38	36	35	34	32	31	30	29	28	27	26	...	89
90	...	96	93	89	86	82	79	76	73	71	68	65	63	61	58	56	54	52	50	48	46	45	43	41	40	38	37	36	34	33	32	31	29	28	27	26	...	90
91	...	96	93	89	86	83	79	76	74	71	68	66	63	61	59	56	54	52	50	49	47	45	43	42	40	39	37	36	35	33	32	31	30	29	28	27	...	91
92	...	96	93	89	86	83	80	77	74	71	68	66	63	61	59	57	55	53	51	49	47	45	44	42	41	39	38	36	35	34	32	31	30	29	28	27	...	92
93	...	96	93	89	86	83	80	77	74	71	69	66	64	61	59	57	55	53	51	49	47	46	44	42	41	39	38	37	35	34	33	32	31	30	28	27	...	93
94	...	96	93	89	86	83	80	77	74	72	69	66	64	62	59	57	55	53	51	50	48	46	44	43	41	40	38	37	36	35	33	32	31	30	29	28	...	94
95	...	96	93	89	86	83	80	77	74	72	69	67	64	62	60	58	56	54	52	50	48	46	45	43	42	40	39	37	36	35	34	33	31	30	29	28	...	95
96	...	96	93	90	86	83	80	77	75	72	69	67	65	62	60	58	56	54	52	50	48	47	45	44	42	41	39	38	37	35	34	33	32	31	30	29	...	96
97	...	96	93	90	86	83	80	78	75	72	70	67	65	63	60	58	56	54	52	51	49	47	46	44	42	41	40	38	37	36	34	33	32	31	30	29	...	97
98	...	96	93	90	87	84	81	78	75	72	70	67	65	63	61	59	57	55	53	51	49	47	46	44	43	41	40	39	37	36	35	34	32	31	30	29	...	98
99	...	97	93	90	87	84	81	78	75	73	70	68	65	63	61	59	57	55	53	51	50	48	46	45	43	42	40	39	38	36	35	34	33	32	31	30	...	99
100	...	97	93	90	87	84	81	78	75	73	70	68	66	63	61	59	57	55	53	52	50	48	47	45	43	42	41	39	38	37	36	34	33	32	31	30	...	100

728. For deducing the mean daily temperature of evaporation from a few observations a **minimum wet-bulb** thermometer is used besides the ordinary one. The method described above (674) for determining the mean air-temperature is inapplicable in this case, because a wet-bulb maximum cannot be relied on. If, through accident or neglect, the muslin surrounding the bulb of this instrument should become partially dry for any time, the mercury will immediately rise above the point which it should have indicated and the range thus obtained would be erroneous. A maximum wet-bulb, therefore, is practically useless. There is no similar objection to the minimum wet-bulb; because, just before sunrise, when cold and moisture are greatest and when the true minimum is reached, there is little danger of the muslin becoming dry, and at any other time such an accident would be immaterial, not affecting the position of the index. The wet-bulb minimum thermometer is similar in construction to the minimum before described (681).

729. The **mean daily** temperature of evaporation, then, is approximately deduced, with the aid of the following table of factors, from the minimum wet reading of the 24 hours, a fixed reading of the wet-bulb (that at 4 P.M. being the one selected) and any other one or more readings of the same. The excess of the 4 P.M. reading over the minimum is multiplied by the mean of the factors corresponding to the three or more indications, as given in the table, tenths of a degree only being retained. Applying this correction (according to its algebraic sign) to the mean of the three or more observations we obtain the approximate mean daily temperature of evaporation.

730. TABLE OF MADRAS HOURLY FACTORS FOR WET-BULB THERMOMETER.*

Hour.	January.		February.		March.		April.		May.		June.	
Minimum ...	+0·67	+0·65	+0·64	+0·64	+0·65	+0·66	+0·67	+0·66	+0·64	+0·63	+0·62	+0·62
4 A.M. ...	+0·50	+0·49	+0·50	+0·51	+0·52	+0·54	+0·55	+0·54	+0·50	+0·48	+0·47	+0·46
5 " ...	+0·57	+0·56	+0·57	+0·59	+0·60	+0·62	+0·63	+0·62	+0·58	+0·57	+0·57	+0·56
6 " ...	+0·64	+0·63	+0·64	+0·64	+0·65	+0·66	+0·64	+0·62	+0·61	+0·61	+0·61	+0·60
7 " ...	+0·53	+0·51	+0·49	+0·46	+0·41	+0·34	+0·27	+0·27	+0·33	+0·38	+0·42	+0·44
8 " ...	+0·03	+0·03	+0·01	−0·02	−0·06	−0·07	−0·05	+0·02	+0·16	+0·22	+0·24	+0·26
9 " ...	−0·31	−0·30	−0·24	−0·22	−0·21	−0·20	−0·15	−0·06	+0·04	+0·12	+0·14	+0·14
10 " ...	−0·44	−0·35	−0·31	−0·29	−0·28	−0·27	−0·23	−0·16	−0·05	+0·01	+0·04	+0·05
11 " ...	−0·49	−0·42	−0·36	−0·35	−0·35	−0·35	−0·34	−0·30	−0·20	−0·10	−0·05	−0·05
Noon ..	−0·52	−0·46	−0·41	−0·40	−0·41	−0·42	−0·45	−0·42	−0·32	−0·22	−0·16	−0·15
1 P.M. ...	−0·51	−0·49	−0·44	−0·43	−0·44	−0·46	−0·47	−0·45	−0·39	−0·32	−0·24	−0·24
2 " ...	−0·48	−0·47	−0·43	−0·42	−0·44	−0·44	−0·43	−0·41	−0·40	−0·38	−0·31	−0·31
3 " ...	−0·42	−0·42	−0·40	−0·40	−0·40	−0·40	−0·40	−0·40	−0·40	−0·39	−0·38	−0·36
4 " ...	−0·33	−0·35	−0·36	−0·36	−0·35	−0·34	−0·33	−0·34	−0·36	−0·37	−0·38	−0·38
5 " ..	−0·22	−0·26	−0·28	−0·28	−0·27	−0·26	−0·25	−0·26	−0·31	−0·34	−0·36	−0·37
6 " ...	−0·13	−0·16	−0·19	−0·19	−0·17	−0·16	−0·15	−0·17	−0·23	−0·28	−0·31	−0·32
7 " ...	−0·07	−0·09	−0·12	−0·11	−0·10	−0·09	−0·08	−0·11	−0·20	−0·26	−0·30	−0·31
8 " ...	−0·01	−0·02	−0·06	−0·07	−0·06	−0·04	−0·03	−0·05	−0·15	−0·22	−0·28	−0·29
9 " ...	+0·04	+0·03	+0·01	−0·01	−0·01	−0·00	+0·02	−0·01	−0·12	−0·20	−0·25	−0·26
10 " ...	+0·08	+0·07	+0·05	+0·04	+0·04	+0·04	+0·03	−0·01	−0·07	−0·14	−0·17	−0·17

* *Vide* note (675).

4 A.M. ...	+0·45	+0·44	+0·42	+0·43	+0·45	+0·48	+0·53	+0·55	+0·55	+0·55	+0·54	+0·53
5 ,, ...	+0·55	+0·53	+0·51	+0·52	+0·57	+0·60	+0·62	+0·64	+0·64	+0·64	+0·63	+0·64
6 ,, ...	+0·59	+0·59	+0·59	+0·61	+0·64	+0·67	+0·68	+0·70	+0·72	+0·72	+0·71	+0·68
7 ,, ...	+0·45	+0·46	+0·44	+0·45	+0·48	+0·46	+0·37	+0·37	+0·41	+0·46	+0·54	+0·56
8 ,, ...	+0·27	+0·28	+0·26	+0·27	+0·29	+0·24	+0·04	−0·02	−0·05	−0·04	−0·01	+0·01
9 ,, ...	+0·15	+0·15	+0·15	+0·15	+0·13	+0·02	−0·15	−0·27	−0·33	−0·33	−0·31	−0·30
10 ,, ...	+0·04	+0·04	+0·03	+0·02	−0·00	0·09	−0·26	−0·39	−0·46	−0·49	−0·50	−0·48
11 ,, ...	−0·06	−0·07	−0·07	−0·07	−0·09	−0·19	−0·34	−0·46	−0·53	−0·57	−0·59	−0·58
Noon ...	−0·17	−0·18	−0·19	−0·19	−0·21	−0·29	−0·39	−0·49	−0·56	−0·57	−0·57	−0·56
1 P.M. ...	−0·27	−0·28	−0·28	−0·29	−0·32	−0·36	−0·45	−0·52	−0·56	−0·58	−0·59	−0·58
2 ,, ...	−0·34	−0·35	−0·36	−0·36	−0·36	−0·37	−0·43	−0·48	−0·50	−0·49	−0·47	−0·46
3 ,, ...	−0·37	−0·38	−0·39	−0·39	−0·38	−0·39	−0·40	−0·41	−0·39	−0·39	−0·40	−0·41
4 ,, ...	−0·39	−0·39	−0·40	−0·39	−0·36	−0·33	−0·32	−0·30	−0·28	−0·28	−0·29	−0·31
5 ,, ...	−0·38	−0·38	−0·39	−0·38	−0·34	−0·29	−0·26	−0·22	−0·19	−0·17	−0·17	−0·18
6 ,, ...	−0·32	−0·32	−0·33	−0·32	−0·29	−0·23	−0·18	−0·13	−0·08	−0·07	−0·08	−0·10
7 ,, ...	−0·29	−0·27	−0·26	−0·25	−0·24	−0·20	−0·14	−0·07	−0·03	−0·02	−0·03	−0·05
8 ,, ...	−0·27	−0·25	−0·23	−0·22	−0·21	−0·18	−0·11	−0·05	−0·01	0·00	0·00	0·00
9 ,, ...	−0·21	−0·18	−0·17	−0·18	−0·20	−0·16	−0·08	−0·01	+0·03	+0·05	−0·04	+0·04
10 ,, ...	−0·14	−0·11	−0·11	−0·12	−0·13	−0·10	−0·02	−0·04	+0·08	+0·09	+0·09	+0·09

731. For **example**; suppose that on the 23rd August the minimum wet-bulb indication was 72°6 and readings at 10 A.M. and 4 P.M. were 76°·1 and 78·°8. The corresponding factors, taken from the right-hand column for August, are + 0·61, + 0·002 and —0·39; the algebraic sum of these being + 0·24, which, divided by 3, the number of observations, gives a mean factor + 0·08. The difference between the 4 P.M. and minimum readings is 6°·2; which, multiplied by the mean factor gives a correction + 0°·5. This added to 75°·8, the mean of the three observations, gives 76°·3 as the approximate mean daily temperature of evaporation.

732. When **regular observations** are taken, the minimum indication and the readings at 10 A.M., 4 P.M. and 10 P.M. of the wet-bulb are used to determine the mean daily temperature of evaporation. The product of the factor for the day by the excess of the 4 P.M. reading over the minimum is added to the mean of the four readings. The factors are as follows:—

From	4th December	to 12th February	0·00
,,	13th February	,, 7th March	0·01
,,	8th March	,, 25th ,,	0·02
,,	26th ,,	,, 9th April	0·03
,,	10th April	,, 19th May	0·04
,,	20th May	,, 5th October	0·03
,,	6th October	,, 25th ,,	0·02
,,	26th ,,	,, 3rd December	0·01

733. The same factors supply the corrections for the monthly or **half-monthly** means, as before described (678) in the case of dry-bulb observations.

734. To estimate the amount of **cloud** the observer looks midway between zenith and horizon and turns slowly round, comparing the clear parts of sky with the clouded. The result is registered in numbers from 0 to 10, the former representing a perfectly cloudless sky, the latter one completely overspread.* Least cloud will be observed at night, most at midday.

735. Finally, the amount and distribution of **rain** have to be observed and registered. The latter means the number of days in the month or year in which any rain

* Continental meteorologists reverse the significance of the numbers in this scale.

falls, and is a point of great importance; because two places having the same amount of rain-fall may differ widely in climate if the whole falls within a short period in one and is evenly distributed over the year in the other. The greatest fall of rain in one day may also be registered with advantage. Rain is measured by the rain-gauge, in inches and hundredths (or cents), the numbers representing the depth to which the surface would be covered with water, if it were horizontal and the rain retained upon it.

736. There is great variety of **rain-gauges**, all of which receive the rain upon a known area and retain it for measurement. The receiving surface should be circular, because this form can be more accurately obtained, by turning, than others. The rain may be collected into a cylinder, the diameter of which bears a known and simple ratio to that of the exposed circle, and measured directly by means of a graduated rod attached to a float and rising above the receiving surface as the water accumulates:* or it may pass into a large movable bottle or other vessel, from which it is removed daily and measured, the capacity of the measure accurately corresponding to the area of the receiving surface†. When used for comparison the funnels must be at the same height from the earth, as it is found that the amount of rain registered decreases with elevation, probably owing to the influence of winds. The average rainfall of a district or country can be ascertained only by many gauges scattered over it, because a simultaneous fall over an extended tract of country is the exception rather than the rule.

737. The following **rules** for the management of rain-gauges are recommended: 1. The gauge should be placed on level ground, at least as many feet from trees, buildings,

---

* Thus if the diameter of the circular receiving surface be 12 inches and the rain be collected in a cylinder of 6 inches diameter, 4 inches of the latter, or on the graduated rod, represent 1 inch of rain: because the areas are in the ratio of the squares of the diameters, or as 4 : 1. This form of guage is obviously unsuitable to places where more than 3 or 4 inches may fall in the 24 hours.

† If the receiving surface be a circle of 4·697 inches in diameter 1 inch of rain will measure exactly 10 fluid ounces. An error of 0·1 inch in the diameter of the funnel will cause an inverse error of 4·26 per cent. If the funnel be 14·854 inches in diameter 100 ounces of water represent one inch of rain.

&c. as these are high. 2. Old gauges should not be abandoned until at least two years after the new ones intended to replace them have been established; in order that the two sets of results may be satisfactorily compared. 3. The receiving surface must be fixed and maintained perfectly level and the entire instrument so planted that neither wind nor other ordinary cause may be able to disturb the level. 4. When the instrument is a float-gauge, allowance must be made for weight of float and rod, and this is generally done by marking the scale so that it shows zero only when a small quantity of water is present. 5. When very heavy rain falls it should be measured as soon as the fall has ceased. 6. In the case of snow one-twelfth of the average depth is counted as rain. 7. Hail is allowed to melt in the funnel and the water measured as rain. 8. The water condensing from dew and fog is measured, when measurable, as rain.

738. PRESSURE is the combined weight of the nitrogen, oxygen, carbon dioxide and aqueous vapor of which the atmosphere consists. It would be difficult and it is unnecessary to determine how far the total pressure is due to each of these constituents. It is sufficient to observe that the humidity is the most variable of the four at any one part of the atmosphere, that which differs most at different parts and, consequently, that which is most influential in producing changes of pressure. As both the quantity and the density of the atmosphere diminish in proportion to distance upwards from sea-level, degree of elevation also affects pressure, so that the latter can be used for measurement of the former. Finally, as pressure is the weight of the entire column of air &c., from the surface of the earth to the upper limit of the atmosphere, information upon the meteorological condition existing and changes occurring in regions far above our reach is given by observations of the pressure at our own positions; while the thermometer and hygrometer are purely local in their indications.

739. The effects of diminished pressure upon health are difficult to isolate from those of concomitant conditions of temperature, humidity, illumination; from personal or national habitudes; from greater or less freedom from floating, material causes of disease, which naturally tend by gravitation to lower levels. The air contains less

moisture in the higher regions, so that evaporation from skin and lungs is freer and urinary water less than below. It is more diathermanous, so that the soil becomes more rapidly heated under the influence of solar heat and cools more rapidly when this is withdrawn. These results are effects of elevation, but only partially of diminished pressure. Without attempting further to separate the causes which produce the complex effect of elevated positions upon the body we may examine it in relation to persons ascending from lower to considerably higher positions, to temporary residents in the latter, and to those who permanently inhabit places of great elevation above sea-level.

740. The heart's action is quickened in persons **ascending** to heights of 2,800 or 3,000 feet above sea-level, as much as 15 or 20 beats in the minute. At greater elevations the superficial blood-vessels become swollen from the expansion of the contained gases, due to diminished pressure; not unfrequently the capillaries of the nasal, aural and pulmonary mucous membranes give way and slight hæmorrhages ensue. The limbs feel lighter and more active. Tissue-change is promoted; appetite and digestive power increase; the nervous system is pleasurably excited and the spirits rise.

741. Healthy persons **temporarily residing** in a mountain climate experience the benefits described above, during their stay, and are capable of greater and more prolonged exertion. The diminution of the amount of oxygen in the volume of inspired air, due to rarefaction, appears to be compensated by increased number of depth of the respirations.* As to the sick, anæmic patients, those suffering from the effects of malaria, hæmorrhage or dyspepsia, from saturnine or mercurial intoxication, from neuralgia, gout or rheumatism, are generally benefited by change to a hill climate. Cases of organic cardiac disease should not be sent to elevations above 3,000 feet; but, below this limit, will not suffer by change from the plains to higher stations. On the other hand rheumatic patients will derive less benefit from the lower positions, where humidity is greater.

---

* The amount of oxygen in a given volume of air varies as the pressure. A cubic foot of dry air at standard pressure contains 130·4 grains oxygen; at 25 inches, $130{\cdot}4 \times \frac{25}{30} = 108{\cdot}6$ grains, one-sixth less.

742. **Inhabitants** of mountain regions appear to suffer more from acute pulmonary affections, as pneumonia, pleuritis and bronchitis, than those who live lower down; but phthisis and other scrofulous diseases are less prevalent. Cholera rarely appears in the higher hill-stations and, if imported, does not spread. Danger from malaria diminishes with elevation; but the line at which complete immunity from it is attained seems to be different in different countries and no general rule can be laid down. In India an elevation of 3,000 feet is probably sufficient to prevent the generation of malaria; but it should be remembered that the poison may be conveyed upwards from lower levels by winds.

743. The **instruments** by which atmospheric pressure is measured are the *barometer* and the *aneroid*, the latter being more convenient by its portability but less generally applicable for scientific purposes.

744. The **barometer** measures the pressure of the air by the height of the mercurial column supported. It consists, threfore, of a cistern (with a bottom movable by a screw) containing mercury, a glass tube closed above (which has been filled with mercury and inverted into the cistern), a brass scale graduated to 0·05 inch and terminating below in a point of ivory, a vernier by which the readings can be carried to 0·002 inch; and a thermometer is attached to the scale, for the purpose of estimating the expansion of the instrument due to temperature. The mercury should have been boiled in the tube before sealing to ensure the complete absence of air and two fixed corrections should have been ascertained.

745. The **corrections** are for capillary attraction and for index-error. The latter is the deviation of the length of the scale, from 30·000 to the end of the ivory point, from 30 inches, and may be either positive or negative. The former is the depression of the surface of the mercurial column due to the capillary action of the tube and is necessarily positive. In different instruments it varies inversely as the diameter* of the tube, as may be seen by the following table :—

*** The diameter of the tube of the standard barometer in the Greenwich Observatory is 0·565 inch, and the correction 0·002 inch.**

Diameter of Tube.				Correction for Capillary Attraction.
0·1 inch	...	...	...	0·070 inch.
0·2 „	...	...	...	0·029 „
0·3 „	...	...	...	0·014 „
0·4 „	...	...	...	0·007 „
0·5 „	...	...	...	0·003 „
0·6 „	...	...	...	0·002 „

Practically, these two corrections are combined into one which may be positive or negative according to the sign and amount of index-error, but which is usually negative. The correction is constant for each instrument and is ascertained by comparison with a standard.

746. The barometer should be **fixed** in a good light but secure from direct solar rays. It should be accurately perpendicular, at such a height that the 30·000 on the scale should be at a convenient level for the observer's eye. Before fixing, the cistern-screw is lowered until the top of the mercurial column falls a little below the top of the tube. If, on complete inversion of the instrument, the absence of the characteristic sound, produced by the fall of the mercury against the top of the tube *in vacuo*, show the presence of air, the barometer, still inverted, but with the mercury again screwed up, must be gently tapped until the air-bubble passes upwards into the cistern. It is then reversed and fixed.

747. To **read** the barometer, turn the screw at the bottom of the cistern until the ivory point of the scale seems exactly in contact with its image in the surface of the mercury. Having noted the indication of the attached thermometer and screwed the vernier into such a position that its front and back lower edges are in line with the top of the mercurial column,* read the scale to twentieths (0·05) with the front lower edge. Observe what line in the latter corresponds exactly to a line on the scale; count the number of vernier divisions from the bottom to that coincidence; each of these represents 0·002 inch, to be added to the height already reckoned on the scale.†

* To make sure of this coincidence the three objects should be looked at from above and below as well as on the apparent level.

† The 25 divisions of the vernier are equal to 24 on the scale, therefore each of the former is one-twentyfifth less than each of the latter,

748. It is clear that the reading thus obtained does not represent the height of the mercurial column or the atmospheric pressure for all temperatures; because all parts of the instrument—mercury, tube and scale—expand, (and not equally) under the influence of heat. All barometrical observations need to be corrected for temperature or **reduced** to what they would be at a certain temperature chosen as a standard, namely 32°F. In practice this reduction is made by means of tables such as the following.* The numbers found at the intersection of the barometer and thermometer columns are to be *subtracted* from the observed height of the column and are *thousandths* of an inch.

or 0″·05 ÷ 25 = 0″·002 less. If then the lowest line of the vernier corresponds to any line of the scale the lowest but one is 0″·002 below the next above. If the vernier be raised until its lowest line but one coincide with that on the scale a little below which it had just been the bottom of the vernier must have been raised 0″·002. If it be elevated until the third line from the bottom coincide with the scale-division immediately above it the amount of elevation must have been 0″·004, and so on. Hence 0″·002 multiplied by the number of vernier divisions between the bottom and the line of coincidence of the two scales represents the distance between the bottom of the vernier (or top of mercurial column) and scale-division next below.

* The formula from which such tables have been prepared is —; $c = h + \frac{m(t - 32) - l(t - 62)}{1 + m(t - 32)}$, in which h is observed height of column; t observed temperature of instrument; m, expansion of mercury for 1°F. (0″·00010001) and l, linear expansion of scale for 1°F. (0″·0000104344).

749. TABLE FOR REDUCTION OF BAROMETER READINGS TO 32° F.

Attached Thermometer.	Reading of the Barometer in inches.										Attached Thermometer.
	22	23	24	25	26	27	28	29	30	31	
31	5	5	5	6	6	6	6	7	7	7	31
32	7	7	8	8	8	8	9	9	9	10	32
33	9	9	10	10	10	11	11	12	12	13	33
34	11	11	12	12	13	13	14	14	15	15	34
35	13	13	14	15	15	16	16	17	17	18	35
36	15	15	16	17	17	18	19	19	20	21	36
37	17	18	18	19	20	21	21	22	23	24	37
38	19	20	20	21	22	23	24	25	26	26	38
39	21	22	23	24	24	25	26	27	28	29	39
40	23	24	25	26	27	28	29	30	31	32	40
41	25	26	27	28	29	30	31	32	34	35	41
42	27	28	29	30	31	33	34	35	36	37	42
43	29	30	31	32	34	35	36	38	39	40	43
44	31	32	33	35	36	37	39	40	42	43	44
45	32	34	35	37	38	40	41	43	44	46	45
46	34	36	38	39	41	42	44	45	47	49	46
47	36	38	40	41	43	45	46	48	50	51	47
48	38	40	42	44	45	47	49	51	52	54	48
49	40	42	44	46	48	50	51	53	55	57	49
50	42	44	46	48	50	52	54	56	58	60	50

TABLE FOR REDUCTION OF BAROMETER READINGS TO 32° F.—(*Continued*).

Attached Thermometer.	Reading of the Barometer in Inches.										Attached Thermometer.
	22	23	24	25	26	27	28	29	30	31	
51	44	46	48	50	52	54	56	58	60	62	51
52	46	48	50	53	55	57	59	61	63	65	52
53	48	50	53	55	57	59	61	64	66	68	53
54	50	52	55	57	59	62	64	66	68	71	54
55	52	54	57	59	62	64	66	69	71	73	55
56	54	57	59	61	64	66	69	71	74	76	56
57	56	59	61	64	66	69	71	74	76	79	57
58	58	61	63	66	69	71	74	76	79	82	58
59	60	63	65	68	71	74	76	79	82	85	59
60	62	65	68	70	73	76	79	82	84	87	60
61	64	67	70	73	75	78	81	84	87	90	61
62	66	69	72	75	78	81	84	87	90	93	62
63	68	71	74	77	80	83	86	89	92	96	63
64	70	73	76	79	82	86	89	92	95	98	64
65	72	75	78	82	85	88	91	95	98	101	65
66	74	77	80	84	87	90	94	97	101	104	66
67	76	79	83	86	89	93	96	100	103	107	67
68	78	81	85	88	92	95	99	102	106	109	68
69	80	83	87	90	94	98	101	105	109	112	69
70	82	85	89	93	96	100	104	107	111	115	70

71	83	87	91	95	99	102	106	110	114	118	71
72	85	89	93	97	101	105	109	113	117	120	72
73	87	91	95	99	103	107	111	115	119	123	73
74	89	93	97	102	106	110	114	118	122	126	74
75	91	95	100	104	108	112	116	120	125	129	75
76	93	98	102	106	110	114	119	123	127	131	76
77	95	100	104	108	113	117	121	126	130	134	77
78	97	102	106	110	115	119	124	128	133	137	78
79	99	104	108	113	117	122	126	131	135	140	79
80	101	106	110	115	119	124	129	133	138	143	80
81	103	108	112	117	122	126	131	136	141	145	81
82	105	110	115	119	124	129	134	138	143	148	82
83	107	112	117	122	126	131	136	141	146	151	83
84	109	114	119	124	129	134	139	144	149	153	84
85	111	116	121	126	131	136	141	146	151	156	85
86	113	118	123	128	133	138	144	149	154	159	86
87	115	120	125	130	136	141	146	151	157	162	87
88	117	122	127	133	138	143	148	154	159	164	88
89	119	124	129	135	140	146	151	156	162	167	89
90	121	126	132	137	142	148	153	159	164	170	90
91	123	128	134	139	145	150	156	162	167	173	91
92	125	130	136	141	147	153	158	164	170	175	92
93	126	132	138	144	149	155	161	167	172	178	93
94	128	134	140	146	152	158	163	169	175	181	94
95	130	136	142	148	154	160	166	172	178	184	95

TABLE FOR REDUCTION OF BAROMETER READINGS TO 32° F.—(*Continued*).

Attached Thermometer.	Reading of the Barometer in Inches.										Attached Thermometer.
	22	23	24	25	26	27	28	29	30	31	
96	132	138	144	150	156	162	168	174	180	186	96
97	134	140	146	153	159	165	171	177	183	189	97
98	136	142	149	155	161	167	173	180	186	192	98
99	138	144	151	157	163	170	176	182	188	195	99
100	140	146	153	159	165	172	178	185	191	197	100

750. The **aneroid** possesses the advantage of requiring no correction, or reduction for temperature. Its index is set by comparison with a standard barometer and it needs no further adjustment. It consists essentially of a cylindrical case, which contains a box made of thin metal, lying near and being parallel to the wall of the case. The box has been exhausted, so that increased external atmospheric pressure alters its form, elongating it to a slight extent. The movement is communicated by levers and wheels to an index moving over a dial. The range of the instrument does not extend beyond 5,000 feet above sea-level and its accuracy is inferior to that of the barometer, though a good instrument will indicate a difference of 4 feet; but its portability adapts it for some purposes, especially for the measurement of heights for sanitary objects when rigid accuracy is unnecessary.

751. The diurnal **fluctuations** of the barometer-indications are remarkably regular, depending chiefly on variations in humidity and these on temperature. From midnight to about 4 A.M. the height of the mercurial column diminishes, increasing during about six hours following and attaining its maximum between 9 and 10 A.M. From this to its principal minimum, between 3 and 4 P.M., it falls regularly and then rises to its secondary maximum which occurs about 10 P.M. The mean varies from day to day but the course of the hourly changes is almost always uniform.

752. Barometrical **undulations** are due to air-currents, increasing or diminishing the total weight of the atmospheric column at the place of observation.

753. Valuable indications of **weather** may sometimes be obtained from observation of undulations of pressure. The absolute height of the column is of little value for this purpose, but if it be much below the mean, storms may be anticipated. In general, a rising mean indicates fair weather and a falling foul. In hot seasons a fall often precedes a thunderstorm. When a change of weather follows immediately upon a barometrical change the new condition is not likely to be lasting. If fine weather and a falling mean are coincident for several days a long period of foul weather may be expected; and *vice versâ.* An undulating column foretells changeable weather. In

the winter of cold climates a rising mean betokens frost. During frost, a rise indicates snow, a fall thaw.

754. The true **daily mean pressure** is obtained from hourly readings of the barometer. A sufficiently close approximation is given, with the aid of the following Table* by the 10 A.M., the 4 P.M. and any other one or more observations. Having found the range (755), multiply it by the mean of the factors given in the Table (756) for the times of observation and apply the product as a correction to the mean of the three or more readings, all having been first reduced to 32°.

755. It is necessary that the 10 A.M. and 4 P.M. readings should be taken, in order to find the barometric **range**; which is the product of the difference between those readings (after reduction to 32°) by the factor appropriate to the date, retaining only three decimal places. These factors are as follows:—

From	29th December	to 14th January	...	1·05
„	15th January	„ 25th „	...	1·04
„	26th „	„ 1st February	...	1·03
„	2nd February	„ 28th „	...	1·02
„	1st March	„ 13th March	...	1·03
„	14th „	„ 25th „	...	1·04
„	26th „	„ 9th April	...	1·05
„	10th April	„ 28th July	...	1·06
„	29th July	„ 14th August	...	1·05
„	15th August	„ 10th September.		1·04
„	11th September	„ 19th „	...	1·05
„	20th „	„ 28th „	...	1·06
„	28th „	„ 13th October	...	1·07
„	14th October	„ 2nd November	...	1·08
„	3rd November	„ 25th „	...	1·09
„	26th „	„ 3rd December	...	1·08
„	4th December	„ 15th „	...	1·07
„	17th „	„ 28th „	...	1·06

* This Table (constructed by Mr. Pogson) is more especially applicable to the eastern and central parts of this Presidency, but may be used for the western without important error.

756. TABLE OF HOURLY RANGE FACTORS FOR BAROMETER.

Hour.	January.		February.		March.		April.		May.		June.	
Night Min. ...	+0·29	+0·27	+0·26	+0·25	+0·23	+0·20	+0·17	+0·16	+0·17	+0·16	+0·12	+0·10
Day Max. ...	−0·54	−0·54	−0·54	−0·53	−0·52	−0·50	−0·49	−0·47	−0·46	−0·45	−0·45	−0·45
Day Min. ...	+0·46	+0·46	+0·46	+0·47	+0·48	+0·50	+0·51	+0·53	+0·54	+0·55	+0·55	+0·55
Night Max. ...	−0·26	−0·25	−0·26	−0·26	−0·25	−0·25	−0·25	−0·26	−0·29	−0·30	−0·26	−0·25
4 A.M. ...	+0·28	+0·26	+0·25	+0·24	+0·22	+0·18	+0·15	+0·14	+0·15	+0·14	+0·10	+0·08
5 " ...	+0·19	+0·19	+0·18	+0·17	+0·14	+0·10	+0·06	+0·06	+0·07	+0·06	+0·03	+0·02
6 " ...	+0·06	+0·06	+0·05	+0·03	0·00	−0·04	−0·06	−0·07	−0·08	−0·09	−0·11	−0·12
7 " ...	−0·14	−0·14	−0·14	−0·16	−0·19	−0·21	−0·22	−0·23	−0·24	−0·25	−0·27	−0·26
8 " ...	−0·37	−0·36	−0·35	−0·36	−0·37	−0·38	−0·39	−0·39	−0·38	−0·38	−0·37	−0·37
9 " ...	−0 52	−0·51	−0·50	−0·49	−0·50	−0·50	−0·49	−0·47	−0·46	−0·45	−0·44	−0·43
10 " ...	−0·51	−0·52	−0·53	−0·52	−0·50	−0·47	−0·44	−0·41	−0·40	−0·40	−0·40	−0·39
11 " ...	−0·38	−0·39	−0·40	−0·39	−0·38	−0·36	−0·33	−0·30	−0·29	−0·28	−0·27	−0·27
Noon ...	−0·16	−0·18	−0·19	−0·18	−0·17	−0·15	−0·14	−0·13	−0·12	−0·11	−0·12	−0·12
1 P.M. ...	+0·10	+0·07	+0·05	+0·05	+0·06	+0·08	+0·09	+0·10	+0·11	+0·10	+0·08	+0·07
2 " ...	+0·32	+0·30	+0·28	+0·27	+0·27	+0·28	+0·29	+0·30	+0·30	+0·29	+0·28	+0·27
3 " ...	+0·45	+0·44	+0·43	+0·43	+0·43	+0·44	+0·45	+0·46	+0·47	+0·46	+0·45	+0·45
4 " ...	+0·44	+0·44	+0·45	+0·46	+0·47	+0·49	+0·51	+0·53	+0·54	+0·55	+0·55	+0·55
5 " ...	+0·36	+0·36	+0·37	+0·39	+0·41	+0·44	+0·47	+0·48	+0·49	+0·50	+0·51	+0·53
6 " ...	+0·24	+0·26	+0·27	+0·29	+0·31	+0·33	+0·35	+0·36	+0·35	+0·36	+0·38	+0·40
7 " ...	+0·07	+0·10	+0·13	+0·15	+0·17	+0·18	+0·19	+0·18	+0·17	+0·18	+0·21	+0·24
8 " ...	−0·11	−0·08	−0·05	−0·03	−0·02	−0·01	0·00	0·00	−0·02	−0·01	+0·03	+0·04
9 " ...	−0·24	−0·21	−0·20	−0·19	−0·18	−0·16	−0·15	−0·16	−0·18	−0·18	−0·13	−0·12
10 " ...	−0·26	−0·25	−0·26	−0·26	−0·25	−0·25	−0·25	−0·26	−0·29	−0·29	−0·24	−0·23

TABLE OF HOURLY RANGE FACTORS FOR BAROMETER—(*Continued*).

Hour.	July.		August.		September.		October.		November.		December.	
Night Min. ...	+0·08	+0·09	+0·10	+0·12	+0·13	+0·14	+0·17	+0·23	+0·28	+0·30	+0·30	+0·30
Day Max. ..	−0·44	−0·43	−0·44	−0·45	−0·46	−0·47	−0·50	−0·52	−0·52	−0·52	−0·52	−0·53
Day Min. ...	+0·56	+0·57	+0·56	+0·55	+0·54	+0·53	+0·50	+0·48	+0·48	+0·48	+0·48	+0·47
Night Max....	−0·26	−0·27	−0·27	−0·27	−0·27	−0·27	−0·27	−0·28	−0·30	−0·32	−0·32	−0·31
4 A.M. ...	+0·08	+0·08	+0·09	+0·09	+0·10	+0·12	+0·15	+0·20	+0·25	+0·28	+0·29	+0·29
5 ,, ...	+0·02	+0·02	+0·03	+0·03	+0·02	+0·03	+0·06	+0·10	+0·15	+0·18	+0·19	+0·19
6 ,, ...	−0·11	−0·10	−0·09	−0·09	−0·09	−0·09	−0·08	−0·05	−0·01	+0·02	+0·04	+0·05
7 ,, ...	−0·25	−0·25	−0·24	−0·24	−0·25	−0·26	−0·25	−0·24	−0·20	−0·18	−0·17	−0·15
8 ,, ...	−0·37	−0·37	−0·38	−0·39	−0·40	−0·40	−0·39	−0·39	−0·38	−0·38	−0·39	−0·38
9 ,, ...	−0·42	−0·42	−0·43	−0·44	−0·45	−0·47	−0·49	−0·51	−0·52	−0·52	−0·51	−0·51
10 ,, ...	−0·38	−0·39	−0·40	−0·41	−0·42	−0·42	−0·43	−0·45	−0·46	−0·47	−0·48	−0·50
11 ,, ...	−0·28	−0·28	−0·28	−0·28	−0·29	−0·29	−0·27	−0·28	−0·30	−0·33	−0·35	−0·37
Noon. ...	−0·11	−0·11	−0·12	−0·11	−0·09	−0·07	−0·05	−0·04	−0·05	−0·08	−0·11	−0·13
1 P.M. ...	+0·08	+0·09	+0·10	+0·12	+0·15	+0·17	+0·18	+0·18	+0·18	+0·17	+0·16	+0·13
2 ,, ...	+0·27	+0·28	+0·29	+0·32	+0·35	+0·36	+0·37	+0·37	+0·38	+0·38	+0·37	+0·35
3 ,, ...	+0·45	+0·45	+0·45	+0·46	+0·48	+0·49	+0·48	+0·48	+0·47	+0·47	+0·46	+0·46
4 ,, ...	+0·56	+0·56	+0·55	+0·55	+0·54	+0·52	+0·50	+0·48	+0·46	+0·45	+0·45	+0·45
5 ,, ...	+0·54	+0·54	+0·52	+0·51	+0·50	+0·48	+0·45	+0·40	+0·37	+0·36	+0·36	+0·36
6 ,, ...	+0·41	+0·41	+0·40	+0·38	+0·35	+0·32	+0·29	+0·25	+0·21	+0·20	+0·21	+0·23
7 ,, ...	+0·24	+0·24	+0·24	+0·21	+0·18	+0·15	+0·11	+0·07	+0·01	0·00	+0·02	+0·04
8 ,, ...	+0·03	+0·03	+0·04	+0·03	0·00	−0·04	−0·08	−0·14	−0·18	−0·19	−0·18	−0·14
9 ,, ..	−0·12	−0·13	−0·14	−0·16	−0·17	−0·20	−0·23	−0·26	−0·29	−0·31	−0·31	−0·28
10 ,, ...	−0·24	−0·24	−0·25	−0·25	−0·26	−0·26	−0·27	−0·28	−0·30	−0·31	−0·31	−0·29

757. Suppose, for **example**, that on the 23rd March the 10 A.M. reduced reading was 29·694, the 4 P.M. 29·540, having 0·154 as difference, which multiplied by 1·04, the factor found in (755) for 23rd March, gives 0·160 for barometric range. Suppose a third reduced reading to be 29·641, at 10 P.M. The factors, taken from the right-hand column for March are — 0·47, + 0·49 and — 0·25; the mean of which is — 0·08. This, multiplied by 0·160, to three decimal places, gives the correction — 0·013. The mean of the three reduced readings is 29·625, from which subtracting 0·013 we obtain 29·612, the approximate mean daily pressure.

758. When the **regular observations**, at 10 A.M., 4 P.M. and 10 P.M. are taken, the mean daily pressure is deduced from the mean of the three reduced readings by subtracting a correction, varying with the time of year and thus calculated. Multiply the barometric range for the day (755) by the mean barometer factor for the same as given below. The product is the correction required.

759. **Mean barometer** factors.

From	16th November	to	20th February	...	— 0·11
,,	21st February	,,	4th March	...	— 0·10
,,	5th March	,,	13th ,,	...	— 0·09
,,	14th ,,	,,	25th ,,	...	— 0·08
,,	26th ,,	,,	2nd April	...	— 0·07
,,	3rd April	,,	14th ,,	...	— 0·06
,,	15th ,,	,,	15th May	...	— 0·05
,,	16th May	,,	4th June	...	— 0·04
,,	5th June	,,	20th ,,	...	— 0·03
,,	21s ,,	,,	22nd July	...	— 0·02
,,	23rd July	,,	14th August	...	— 0·03
,,	15th August	,,	3rd September	...	— 0 04
,,	4th September	,,	19th ,,	...	— 0·05
,,	20th ,,	,,	2nd October	...	— 0·06
,,	3rd October	,,	13th ,,	...	— 0·07
,,	14th ,,	,,	25th ,,	...	— 0·08
,,	26th ,,	,,	2nd November	...	— 0·09
,,	3rd November	,,	15th ,,	...	— 0·10

760. The monthly or **half-monthly** mean pressure is obtained by dividing the sum of the daily means, obtained as described above, by the number of days; or by applying to the uncorrected mean deduced from the three daily

observations a monthly or half-monthly correction. In the following table the barometric range and mean barometer factors are given for half-months. The mean of the observed ranges multiplied by the barometric range factor (to three decimal places) gives the half-monthly range; which, multiplied by the mean barometer factor, gives the correction to be *subtracted* from the uncorrected mean.

761. TABLE OF HALF-MONTHLY BAROMETER FACTORS.

—	Sign.	January.		February.		March.		April.		May.		June.	
Barometric Range	+	1·05	1·04	1·02	1·02	1·03	1·04	1·05	1·06	1·06	1·06	1·06	1·06
Mean Barometer..	—	0·11	0·11	0·11	0·10	0·09	0·08	0·06	0·05	0·05	0·04	0·03	0·02

—	Sign.	July.		August.		September.		October.		November.		December.	
Barometric Range	+	1·06	1·06	1·05	1·04	1·04	1·06	1·07	1·08	1·09	1·09	1·07	1·06
Mean Barometer..	—	0·02	0·03	0·03	0·04	0·05	0·06	0·07	0·08	0·10	0·11	0·11	0·11

762. The mean annual height of the mercurial column at **sea-level** is different in different parts of the world. At the equator it is 29·974 and increases towards the poles up to 30 degrees of latitude. It then diminishes in both hemispheres; especially in the southern, so that between 63° and 74° south it is an inch lower than at the equator.

763. On maps **isobaric** lines pass through places having the same mean annual atmospheric pressure.

764. Pressure diminishes as we ascend above sea-level because the quantity of air above us becomes less; but not uniformly, because the atmosphere is less dense in proportion to elevation. The greater the height above the sea the greater must be the number of feet to be ascended in order to produce a given depression of the mercurial column. These facts are illustrated by the following table, which affords a rough method of **measuring heights.** The reduced readings before and after ascent give the depression; and the number of feet corresponding is corrected for temperature by multiplying it by

$$1 + \frac{t + t' - 64}{900},$$

t and t' being the temperatures of the points left and reached.

765. Table for Rough Measurement of Heights.

Depression of Mercury in Inches.		Ascent in Feet.
From	To	
31	30	857
30	29	886
29	28	918
28	27	951
27	26	986
26	25	1,025
25	24	1,068
24	23	1,113
23	22	1,161
22	21	1,216
21	20	1,276
20	19	1,341
19	18	1,413

766. As this method assumes that temperature and pressure remain constant at each point during the ascent, it is obviously unsuited to cases where **accurate measurement** is required. For this purpose precisely simultaneous readings of two good barometers, at the two points the difference between whose heights above sea-level is to be ascertained, are desirable. If this is impracticable the barometer should be carefully compared before starting and after return with that in the nearest Meteorological Station, and the regular observations made at the latter compared with the traveller's. Besides noting the attached thermometer for reduction, the indications of an accurate thermometer freely exposed in the shade are to be recorded. If the places are only a few miles asunder two or three readings are generally sufficient; if the interval be considerable, half-monthly means should be compared. From these data and the Table following differences in height can be calculated with almost absolute accuracy.

767. TABLE FOR CALCULATING HEIGHTS.

Barometer reduced.	Height in Feet.	Difference.	Barometer reduced.	Height in Feet.	Difference.	Barometer reduced.	Height in Feet.	Difference.
22·0	9,347	124	25·0	5,863	109	28·0	2,774	97
22·1	9,223	123	25·1	5,754	108	28·1	2,677	97
22·2	9,100	122	25·2	5,646	108	28·2	2,580	96
22·3	8,978	122	25·3	5,538	108	28·3	2,484	96
22·4	8,856	122	25·4	5,430	107	28·4	2,388	96
22·5	8,734	120	25·5	5,323	106	28·5	2,292	96
22·6	8,614	120	25·6	5,217	106	28·6	2,196	95
22·7	8,494	120	25·7	5,111	106	28·7	2,101	95
22·8	8,374	119	25·8	5,005	106	28·8	2,006	94
22·9	8,255	119	25·9	4,899	105	28·9	1,912	94
23·0	8,136	118	26·0	4,794	105	29·0	1,818	94
23·1	8,018	118	26·1	4,689	104	29·1	1,724	94
23·2	7,900	117	26·2	4,585	104	29·2	1,630	93
23·3	7,783	117	26·3	4,481	103	29·3	1,537	93
23·4	7,666	116	26·4	4,378	103	29·4	1,444	92
23·5	7,550	116	26·5	4,275	103	29·5	1,352	92
23·6	7,434	115	26·6	4,172	102	29·6	1,260	92
23·7	7,319	115	26·7	4,070	102	29·7	1,168	92
23·8	7,204	114	26·8	3,968	102	29·8	1,076	91
23·9	7,090	114	26·9	3,866	101	29·9	985	91
24·0	6,976	113	27·0	3,765	101	30·0	894	91
24·1	6,863	113	27·1	3,664	100	30·1	803	90
24·2	6,750	113	27·2	3,564	100	30·2	713	90
24·3	6,637	112	27·3	3,464	100	30·3	623	90
24·4	6,525	112	27·4	3,364	99	30·4	533	90
24·5	6,413	111	27·5	3,265	99	30·5	443	89
24·6	6,302	110	27·6	3,166	98	30·6	354	89
24·7	6,192	110	27·7	3,068	98	30·7	265	89
24·8	6,082	110	27·8	2,970	98	30·8	176	88
24·9	5,972	109	27·9	2,872	98	30·9	88	88

768. The following **example** (taken, with the Table, from Mr. Pogson's *Meteorological Reduction Tables*) will explain the method of procedure. The barometer indications having been reduced to 32°, the difference between

the corresponding heights, as found in the Table, is corrected for temperature; the correction factor being the sum of the shade temperatures at the two places and 900, divided by 1,000, which is multiplied into the tabular difference between the heights. Thus; at Yercaud on the 27th March 1869, Captain Edgcome, R.E., took three observations, at 9-30 A.M., 12-30 P.M., and 4-30 P.M. The reduced readings and corresponding temperatures in shade were—

25·42	25·41	25·33
74°·0	76°·5	77°·0

The means were 25·387 and 75°·8. To find the corresponding Salem figures: a reference to the Meteorological Register gives, for the same date, mean daily pressure 28·984, range 0·149; mean daily temperature 90°·3, range 26°·3. The barometer range factors for the Yercaud times of observation are (756) — 0·49, — 0·04, + 0·47; of which the mean is — 0·02. This multiplied by the range, 0·149, gives a correction — 0·003, which applied, with a contrary sign (758) to daily mean gives 28·987 for barometer reading at Salem corresponding to mean of the three Yercaud readings. A similar process give 97°·1 for thermometer reading. We have therefore for comparison—

	Barometer.	Thermometer.
Yercaud	25·387	75°·8
Salem	28·987	97°·1

The corresponding heights as found from the Table are 5,444 and 1,830 feet* giving a difference of 3,614. The sum of the temperatures, *plus* 900, is 1072·9; giving, when divided by 1,000, a correction 1·0729. This multiplied by 3,614 is 3,877 feet, the height of Yercaud above Salem.

769. Air in MOVEMENT constitutes wind, chiefly the result of inequalities of temperature at different parts of the atmosphere. The addition of aqueous vapor to air, also, renders it specifically lighter and causes it to rise.

* In the Table 25·3 corresponds to 5,538, from which is subtracted 0·87 of 108, the number found in the "difference" column. 87 × 1·08 = 93·96; which, taken from 5,538 leaves 5444·14. So 28·9 gives 1,912 — 0·94 × 87 = 1,912 — 81·78 = 1830·22.

Heavier air, generally but not necessarily cooler, coming to supply the place of that which has risen, produces the surface winds; the lighter air spreads out laterally in the upper regions of the atmosphere and its course is often indicated by the movement of the higher clouds. The causes of winds being thus complex and variable, they are generally partial and irregular. The *trade-winds*, the *land-wind* and the *sea-breeze*, however, are regular and periodic air-currents which may be briefly noticed.

770. The **trade-winds** are surface-currents blowing from the polar towards the equatorial regions, to replace the heated air which has risen from the latter and which flows above the trade-winds and in opposite directions to them. Their primary courses are southward in the northern hemisphere and northward in the southern; but as they reach in succession parts of the earth's surface which rotate eastwardly with greater velocity than that with which they, moving eastward at the rate of circumpolar rotation only, are travelling, they are, as it were, left behind by the intertropical surface, with the apparent effect of making them north-eastern in the northern and south-eastern in the southern hemisphere. They prevail in a belt extending about 30° at each side of the equator. To the trade-wind of this hemisphere our north-east monsoon is due.

771. On the coasts of intertropical lands the more rapid radiation of heat from the land, at night, than from the sea cools relatively the air in contact with the former; which, therefore, being heavier presses seaward and generates the **land-wind**. During the day, on the contrary, the land absorbs the solar heat more rapidly than the water, heats it and produces an upward current compensated by an in-draught from the surface of the sea, the **sea-breeze**.

772. **Cyclones** are rotatory storms generated by the collision of opposing air-currents. The centre or focus of the storm moves on with a velocity much below that of the wind itself. The length of the diameter of rotation varies from 50 miles to more than 200. In our northern hemisphere the direction of rotation is contrary to that of the hands of a watch; so that if the observer faces the wind

the centre of the cyclone is on his right. In the southern hemisphere the direction in reversed.

773. The direct **effects** of wind are a complex result of its velocity, temperature and humidity. It rarely or never heats the body, so that it is only necessary to consider it as a cooling agent. A cold wind chills in proportion to its velocity: a hot one, if moist, scarcely affects temperature; while, if dry, it cools by promoting evaporation. In calm air a low temperature is much more easily borne than in a breeze, which remove successive strata of warmed air, replacing them with cold. Indirectly, wind may promote health by aiding ventilation; or disease by spreading the agents of infection. Thus malaria may be blown upward by the wind to considerable heights above its source; or horizontally to a distance of some miles. In the latter case the distance to which the poison may be wafted is much diminished if water, and salt-water more especially, lie in its course.

774. Besides the *direction*, *velocity* and *pressure* of the wind, the **observer** should note the times at which it begins and subsides, or suddenly changes its course; the direction of changes; the point from which it blows steadily after alterations or fluctuations; the existence of currents in the upper regions of the atmosphere (shown by cloud-movements); the times when hot or cold winds set in and the points from which they blow; the connection of weather—cloudy, rainy or fine—with the quarter from which the wind is blowing, or has been blowing for some time previously.

775. The **direction** of wind is known by a vane, which should be placed so as to be out of shelter of trees or buildings and the eddies which they are apt to produce. The points should be set by the stars not by the compass, unless the variation of the needle be known. The indicator should be examined occasionally to see that its movements are perfectly free. Sixteen of the thirty-two points of the compass will be enough to note and register. They are registered by numbers, N. being 0 or 32 and S. 16; the odd ones being omitted. In ordinary Meteorological Stations observations are made at 10 A.M. and 10 P.M.

776. The **mean direction** is generally calculated by adding together the number representing the points noted

and dividing by the number of observations. If no two points observed differ by more than 16—in other words, if all the points, projected on a circle, are in the same semicircle—this method may be used. Otherwise, the points observed should be represented on the circumference of a circle by marks in positions corresponding to the observations; when the eye can determine which part of the circle would gravitate lowest if the marks were weights, and this part indicates the mean direction. As, however, the varying velocity of the wind is not taken into consideration in the observations the determination of the mean direction is of little practical utility.

777. **Velocity** is measured and registered by the anemometer, of which there are several kinds, Robinson's being the best adapted to our purpose. In this instrument four hemispherical cups, fixed at the ends of two horizontal rods at right angles, receive the pressure of the air-current and revolve round an axis passing through the intersection of the rods. The movement is communicated to wheels, by means of which its rate is read off at fixed hours. The velocity of rotation of the cups is practically one-third of that with which the wind is moving, so that the number of revolutions corresponding to a mile bears a fixed relation to the distance between the cups. The large and costly self-recording anemometers can be relied on as having been constructed with sufficient accuracy to give the rate of movement of the wind directly. The smaller instruments are carefully compared, through one or two thousand miles, with a standard and the relation of revolutions to miles thus ascertained. The velocity of wind rarely exceeds 40 miles an hour; cyclones revolve at a rate of 100 to 110, but the maximum velocity is still unknown.

778. The **wind-resultant** is compounded of direction and velocity and gives the position which a body, freely moving under the influence of wind alone, would occupy after a given time. It is obviously most important for sanitary purposes; being capable, for instance of determining whether malaria or other material poison has been borne by the wind from one place to another. It requires, however, frequent observations and complicated calculations and is, unfortunately, rarely attainable.

779. The force or **pressure** of the wind may be calculated from the velocity or estimated directly by a wind-gauge. V, the velocity in miles per hour, being ascertained, P, the pressure in pounds on the square foot, $= 0{\cdot}005 \cdot V^2$.* The following Table† has been constructed to save the labor of calculation, and gives either velocity or pressure from the other:—

* Conversely the velocity may be calculated from the pressure, by the equation $V = \sqrt{200 P}$.

† From Sir H. James' Tables.

Table for Calculating Velocity or Pressure of Wind.

Pressure.	Velocity.	Pressure.	Velocity.	Pressure.	Velocity.	Pressure.	Velocity.
oz.	Miles.	lbs.	Miles.	lbs.	Miles.	lbs.	Miles.
1·00	3·535	7·25	38·078	17·25	58·736	27·25	73·824
2·00	5·000	7 50	38·729	17·50	59·160	27·50	74·161
3·00	6·123	7·75	39·370	17·75	59·581	27·75	74·498
4·00	7·071	8·00	40·000	18·00	60·000	28·00	74·833
5·00	7·905	8·25	40·620	18·25	60·415	28·25	75·166
6·00	8·660	8·50	41·231	18·50	60·827	28·50	75·498
7·00	9·354	8·75	41·833	18·75	61·237	28·75	75·828
8·00	10·000	9·00	42·426	19·00	61·644	29·00	76·157
9·00	10·606	9·25	43·011	19·25	62·048	29·25	76·485
10·00	11·180	9·50	43·588	19·50	62·449	29·50	76·811
11·00	11·726	9·75	44·1[illegible]	19·75	62·849	29·75	77·136
12·00	12·247	10·00	44·721	20·00	63·245	30·00	77·459
13·00	12·747	10·25	45·276	20·25	63·639	30·25	77·781
14·00	13·228	10·50	45·825	20·50	64·031	30·50	78·102
15·00	13·693	10·75	46·368	20·75	64·420	30·75	78·421
lbs.							
1·00	14·142	11·00	46 904	21·00	64·807	31·00	78·740
1·25	15·811	11·25	47·434	21·25	65·192	31·25	79·056
1·50	17·320	11·50	47·958	21·50	65·574	31·50	79·372
1·75	18·708	11·75	48·476	21·75	65·954	31·75	79·686
2·00	20·000	12·00	48·089	22·00	66·382	32·00	80·000
2·25	21·213	12·25	49·407	22·25	66·708	32·25	80·311
2·50	22·360	12·50	50·000	22·50	67·082	32·50	80·622
2·75	23·452	12·75	50·497	22·75	67·453	32·75	80·932
3·00	24·494	13·00	50·990	23·00	67·823	33·00	81·240
3·25	25·495	13·25	51·478	23·25	68·190	33·25	81·547
3·50	26·457	13·50	51·961	23·50	68·556	33·50	81·853
3·75	27·386	13·75	52·440	23·75	68·920	33·75	82·158
4·00	28·284	14·00	52·915	24·00	69·282	34·00	82·462
4·25	29·154	14·25	53·385	24·25	69·641	34·25	82·764
4·50	30·000	14·50	53·851	24·50	70·000	34·50	83·066
4·75	30·822	14·75	54·313	24·75	70·356	34·75	83·366
5·00	31·622	15·00	54·772	25·00	70·710	35·00	83·666
5·25	32·403	15·25	55·226	25·25	71·063	35·25	83·964
5·50	33·166	15·50	55·677	25·50	71·414	35·50	84·261
5·75	33·911	15·75	56·124	25·75	71·763	35·75	84·567
6·00	34·641	16·00	56·568	26·00	72·111	36·00	84·852
6·25	35·355	16·25	57·008	26·25	72·456	36·25	85·146
6·50	36·055	16·50	57·445	26·50	72·801	36·50	85·440
6·75	36·742	16·75	57·879	26·75	73·143	36·75	85·732
7·00	37·416	17·00	58·309	27·00	73·484	37·00	86·023

780. Lind's **wind-gauge** is a U-shaped glass tube, about half-an-inch in diameter with one end bent again at right angles so as to be open horizontally to the wind, the other end being also open but covered. The tube being half filled with water, the wind blowing in at the open end forces up the water in the other leg; and the height to which it rises, measured by a scale, indicates the pressure exerted by the current. The instrument revolves on a perpendicular axis so that a vane turns the open end of the tube directly towards the wind. Of course the pressure at the moment of observation only is indicated by this instrument. The following Table (from Mr. Drew's work) illustrates the use of the wind-gauge:—

Inches.	Force in lbs.	Common designation.
6·0	31·75	Hurricane.
5·0	26·04	Very great storm.
4·0	20·83	Great storm.
3·0	15·62	Storm.
2·0	10·42	Very high wind.
1·0	5·21	High wind.
0·5	2·60	Brisk gale.
0·1	0·52	Fresh breeze.
0·05	0·26	Pleasant wind.
0·0	0·00	Calm.

781. There can be no doubt that the ELECTRICITY of the atmosphere exercises a powerful influence, through the nervous system, upon the sanitary condition of men and other animals and probably also of plants; but the connection between the two has been little studied. The few following facts may be noted. The atmospheric electricity is generally positive, while that of the earth's surface is negative; but sometimes, as in foggy weather, these conditions are reversed. Falling rain-drops are often negatively electrified while the air through which they pass is positive. Atmospheric electricity has two maxima, shortly after sunrise and sunset; and two minima, one at about 2 or 3 P.M. and one during the night. In the winters of Europe the intensity of atmospheric electricity

is much greater than in the summers; that in January, in Brussels, being 13 times as great as that in July.

782. The hygienic influence of LIGHT is only now beginning to be inquired into. Its general good effects upon growth and convalescence are established: and it is probable that the death-rate of the children of the poorer classes in this country would be higher than it is were it not that conditions unfavorable to vitality are partially compensated by free exposure to light.

CHAPTER X.

MILITARY AND VILLAGE HYGIENE.

783. The facts, principles and rules of the foregoing pages are no less applicable to the military than to the civil condition. As, however, soldiers are more under control than civilians and their governors can more directly influence them in sanitary matters, both for good and evil, it has been thought desirable to add a few paragraphs on MILITARY HYGIENE, having especial reference to the Native Army.

784. In the laying out of new **lines** or improvement of old ones, the importance of the freest ventilation should be remembered. Streets should be straight and wide, and so laid out as to secure perflation by the prevailing wind, if not malarious. Trees should be planted along the streets for shade, and in malarious localities a belt should be interposed between the lines and the source of malaria. Pools of stagnant water and accumulations of putrescible refuse should be impossible. The air from which the dwellings are supplied must be carefully preserved from pollution.

785. The **water** should be periodically examined, especially with regard to organic matter and ammonia, free and albuminoid. If these are absent, or present in minute quantity only, nitrates and sodium chloride may be disregarded unless their amount impairs the taste of the water. Condemned sources, if incapable of improvement by cleaning and lime, should be filled up, especially if they are situated near the lines; there being no other security for their disuse. The common opinion of natives when unfavorable to an old source of supply is always worthy of attention and inquiry into its foundation; but they will use with relish and approval waters which are demonstrably unwholesome. Sanctioned wells should be protected from contamination by the precautions described in Chapter III. Tanks receiving surface-drainage and those to which cattle have access are undesirable sources of water-supply unless their size is very considerable; and, even in

this case, water for domestic use should be taken from a part as remote as possible from those places where nullahs enter or cattle drink. The same caution applies to washing-places for persons or clothes. Rivers often yield a doubtful supply; and wells sunk near the bank are to be preferred to the stream itself. The vessels used for raising and conveying water require periodical supervision and the places where they are kept should be known and inspected.

786. Little can be done with regard to the quality of the sepoy's **food** beyond watching the regimental bazaar to prevent the sale of putrid or diseased meat or of decaying fruit and vegetables, and encouraging gardening as a means of supplying the latter in greater abundance and of better kinds than would otherwise be obtainable. Food is more often deficient in quantity than defective in quality. The sepoy's pay though slightly improved of late years is still, compared with the prices of his ordinary provisions, much below its original amount and insufficient for the support of himself as an effective soldier and a numerous immediate and collateral family besides. It is not possible to control the expenditure of his small pay; but something may be done to avert the slow starvation of himself and wife and children by the rigid exclusion from the lines of all other relatives and connections; with the exception, perhaps, of his parents. In many stations, where waste land abounds, the keeping of goats and cows should be encouraged, to improve the milk-supply; but these animals should be kept away from the quarters.

787. As to choice of **sites**, temporary or permanent, nothing need be added to what has been laid down in Chapter V.

788. Sepoy's **houses** should be built by the State; not upon "standard plans" prepared for and suited to any one part of India, but after various patterns adapted to the local circumstances of each station as to climate. They should be in single rows if possible, each with a small yard; but if space does not admit of this and double rows are necessary there should be no vacant space between the backs of the ranges, in which refuse can accumulate. Ventilation of the houses must of course be provided for: but there is always a danger of over-ventilating the

quarters which Europeans devise for Natives; an error which sometimes increases sickness amongst prisoners and which, in the case of free persons, would defeat its own object by leading to the closure of every opening. House-drains and street-drains should be regularly flushed. The dry-earth system of disposing of excreta can be carried out at small expense and the house-latrine can be so arranged as to admit of their periodical removal by sweepers from without. Carts should traverse the lines at noon and sunset to carry away the excreta and other refuse, which can be utilized in the gardens.

789. The discomfort, and therefore the inefficiency, arising from the unhappy practice of **clothing** the sepoy in pseudo-European fashion are shown by his hastening to divest himself of every trace of it as soon as parade is over. Even if he did not persist in wearing a more or less bulky native garment round his loins, under the trowsers, the experiment of asking him to pick a pin from off the ground when dressed for duty will demonstrate the unsuitability of his equipment to an employment which demands the most unrestricted freedom of action for every muscle and every joint. In the case of the soldier, whose work is mainly physical, even more than in that of the civilian, clothing should be so cut and so arranged that no pressure should interfere with respiration or circulation or with the movement of the limbs. The entire dress of the regular native soldier, from his shako to his boots, needs to be reformed; and the vicious tendency towards making him a bad imitation of his British brother in arms replaced by efforts to have him clothed and equipped in a manner adapted to his duties, his climate and his previous habits.

790. Closely connected with dress is the carriage of those military **burdens** which cannot be dispensed with in active service. Without entering into details on this subject it may be laid down that the weights should be reduced to the lowest point compatible with efficiency and should be, whenever it is practicable, carried for the men; and that they should be so arranged as to be borne with the least possible discomfort and muscular effort.

791. The **arrangement** of the knapsack &c. should be such that no undue pressure can be exerted upon the

vessels and nerves of the neck or axilla or any obstruction offered to the full expansion of the chest in respiration, or to the action of the lower extremities in marching or of the upper in using the weapons. Further; the weights should be placed as near as possible to the centre of gravity of the body or in the line of the perpendicular from that point to the ground, so that the maintenance of the erect position shall demand the least possible amount of muscular effort. The centre of gravity, in the upright posture, is about midway between the umbilicus and pubis and the perpendicular falls in front of the os calcis; and, prolonged upwards, passes through the top of the skull. Hence the most favorable parts on which to rest the weights, (next to the top of the head which is inadmissible in the present case), are the shoulders, and the sides and back of the pelvis.

792. While it is a mistake to compel the soldier to carry his weights unnecessarily in time of peace, under an idea that habit will render them less burdensome in active service, no effort should be neglected which, by means of **physical training**, may increase respiratory and muscular power. Of late years great improvements in this direction have been effected in European armies, but little or nothing has been done for Native troops. In some regiments the *gymkhana* is feebly encouraged by one or two officers individually; in others a few men are induced to join in cricket; a game which, in itself uninteresting to all but the minority who play well and to others who have been trained to like it, is unsuited to the climate and to native habits; and involves a disproportionate amount of inaction. The establishment of regimental gardens has been an excellent step; but beneficial rather by improving the supply of vegetables, eking out the sepoy's scanty pay and giving him healthful employment during his leisure hours than through the physical exercise which it entails. The association of road-making with convict-labor renders it an unsuitable employment for sepoys; but military or quasi-military work, such as entrenching positions, demolition of old fortifications &c., might often be found for them, with advantage to their health and pocket. There is great room for improvement in the physique of our native soldiers and systematic efforts towards it should be made. Regular gymnasia under skilled management should be established

and practice in them might replace with advantage some of the dreary drill-parades whose frequency and monotomy too often weary mind and body without improving either. Route-marches (without boots) might be more frequent than they generally are. In many stations swimming and rowing, excellent exercises and accomplishments likely to be eminently useful in this country in a compaign, might be taught and practised regularly. It would be desirable that a young officer of athletic habits and some knowledge of hygiene should be detailed to superintend and control the exercises; but there is probably less danger of over-exertion with Natives of this Presidency than there often is with Europeans. The gymnastics of recruits should be watched by the medical officer.

793. No duty of the regimental Surgeon is more important and none is liable to be more perfunctorily performed than the passing of **recruits.** The limits of height and measurement of thorax are laid down by regulation and vary from time to time according to the demand for men. Obvious deformities or deficiencies or a state of actual ill-health lead to rejection, of course; but defective sight, hearing or articulation, looseness or absence of teeth, slight enlargements of liver or spleen, stricture of the urethra, the scars of syphilitic sores, internal piles and many other things likely seriously to impair or to destroy the efficiency of the soldier, after a longer or shorter interval, may escape notice if not remembered and looked for by the examining officer. As a general rule recruits are admitted young, before the processes of growth are completed. Care should, therefore, be taken that they are not over-drilled or otherwise over-worked. Sepoys should not be called upon to perform the complete routine of military duty, even in time of peace until they have attained the age of 20.

794. The duties of the Madras Army are spread over so wide an extent of country, including great varieties of **climate,** that the sepoy must be prepared to encounter conditions of temperature and humidity which differ considerably from those of his native district. Carefully selected in the first instance, and supplied with good food and clothing and adequate shelter, he can be maintained in a state of thorough efficiency provided his term of

service in the more unfavorable climates be not unduly prolonged and that the reliefs be so arranged as not to allow a tour in an unhealthy district to be succeeded by one in another district of similar unhealthiness. A regiment should not, for example, be moved, in the ordinary course of reliefs, from Burmah to the Western Coast. This has, however, been done at times.

795. While the larger towns are either managed by municipalities or, as being head-quarters of officers, European or Native, who know something of sanitation and care a little for sanitary improvement, the smaller towns and the **villages** are likely to be entirely neglected. In these greater obstructiveness may be expected; and greater tact will be required in dealing with them, in order to avoid exciting opposition and confirming prejudices against sanitary measures, which are no less strong in the rural populations of India than in the corresponding classes in Europe. In some respects the task of improving the sanitary condition of villages is easier in this country than in the West. We have to deal with people accustomed to submit to authority and to obey orders, even when the object of them is not seen, provided they do not run counter to customs which have, or are believed to have, a religious sanction. Insanitary practices which have their root in hereditary dread of rapine—as, for instance, the keeping of the farm-cattle in the village and in the dwelling-house—are very difficult to deal with, but may in some cases be suppressed by the exercise of a little firm authority combined with tact and patience. In dealing with villagers (as also, indeed, with the inhabitants of cities and towns), the principles to be borne in mind are:—that in the present state of education in hygiene, no change should be forcibly made in the habits of the people unless its sanitary advantages are undisputed; that no pecuniary loss should be inflicted without compensation; that the reasons for every measure should be explained as clearly as may be possible in the circumstances; that the co-operation of leading inhabitants, or at least their consent, should be sought; and that, when opportunity offers, model villages or streets should be built, to teach by example.

796. For the improvement of the **air** of villages much may be done. The accumulation of manure-heaps in the house-yards may, and in the street must, be forbidden.

Each occupier may fairly be made responsible for the freedom from filth of that portion of the street which lies before his dwelling, including the drain. The lower branches of trees, which obstruct ventilation, should be removed. Unoccupied house-sites should be levelled, cleared and planted. Old ramparts and bastions should be destroyed, old moats filled up. Quarry-holes and gravel-pits which have ceased to be useful for their original purposes and have become receptacles for filth, must be filled with earth. Burials or burnings of the dead within village limits may be peremptorily forbidden. The practice of keeping cattle at night in enclosures outside villages should be encouraged, and the ryots themselves might be impressed with the advantage and economy of residing on their own lands, instead of crowding the village with their houses and cattle-sheds. In small towns and villages latrines are unnecessary and irritating; but the fouling of streets and lanes should be not only forbidden but punished.

797. Natives are fastidious about the **water** they drink, after their own fashion; which is not, unfortunately, a fashion which sanitary authorities approve. It is to be feared that, in some cases at least, drinking-water not contaminated with animal impurities is considered insipid: it is certain that no objection is felt to drawing water for domestic use from tanks in which cattle, foul clothes and fouler bodies are habitually washed. In spite of these drawbacks something may be done to improve the water-supply of villages and thereby to improve the general health of the inhabitants and to check the spread of infectious diseases. All wells liable to receive water which has percolated through graves should be filled up. Old street-wells should be cleaned out and deepened, protected by parapets from surface-drainage and by sloping platforms and drains from re-percolation of water drawn and spilled about. When the supply is obtained from tanks, one or more of these should be assigned to domestic purposes and carefully guarded from cattle, bathers and washers of clothes. When the sites of the villages are old, and consequently soaked with filth, the sinking and use of new wells outside village limits should be encouraged. The water-supply of parch[illegible]es requires special attention and is often overlooked. The habits of the servile castes are dirtier

and more careless than those of ordinary villagers; and village authorities are apt to overlook entirely the sanitary condition of the parcherries, even after they have learned to take some interest in their own. In times of drought low-caste people sometimes suffer severely from scarcity and impurity of water, while the neighboring village is fairly supplied.

798. It may be generally assumed that the **soil** on which a village stands is saturated with impurities of animal and vegetable origin. The transfer of the inhabitants to a fresh and uncontaminated site is rarely practicable: but occasionally the opportunity does occur and in this case the new position can be selected by authority and with due regard to hygienic principles, as laid down in Chapter V. Less rarely something may be done by discouraging the re-occupation of old house-sites in villages; which, as already suggested, should be levelled and planted, and so preserved from again becoming sites for dwellings. Ground for new buildings should be granted only outside, and as far outside as possible, old limits. The surface of pits and pools which may have been filled up, not with clean earth, clay or gravel, but with putrescent rubbish, should never be built upon; and the sites and neighborhood of disused grave-yards or burning-grounds must be avoided with equal care. The revenue regulations in India tend perhaps in some degree to maintain a low sanitary condition in villages. The village-site is held free of taxation, whereas any portion of the cultivated area, occupied by houses or sheds, has to be paid for. Every man tries to cultivate all his holding, and so the people are induced to crowd inconveniently the village-site.

799. The interior of a native **dwelling** is generally neat and clean, and its plan favorable to ventilation and to health. Its weak points are deficiency of air-space for its inhabitants and insufficient ventilation of its separate chambers; the evil results of which, however, are much modified by the custom of the people spending so much of their time out of doors. The former evil is too often aggravated by the practice of housing cattle, fowls &c. in the dwelling. The court and the yard are not kept so cleanly as the house and in them refuse matters are often permitted to accumulate. Little can be done directly to

improve village habitations: but advantage should always be taken of the erection of quarters for sepoys, police, jail-warders or officials of any kind to exhibit models of what houses should be; of various dimensions, suitable to various conditions of life. Such model dwellings should not be clumsy imitations of an English cottage, but should follow the general plan which has been adopted by the natives of the country as best suited to their climate and their habits. Another caution may be added. Too much zeal for ventilation will do more harm than good. Natives may be over-ventilated: and if excessive provision for the entrance of fresh air be made they will, if free, remedy the discomfort by excluding it altogether.

CHAPTER XI.

EPIDEMICS AND EPIZOOTICS.

800. An EPIDEMIC is a disease which prevails extensively amongst the human inhabitants of a place at a particular time, being communicated from one case to another by contagion or infection. The specific poison of each epidemic disease is probably peculiar to it and incapable of conversion into the exciting cause of another. Whether these specific poisons are living germs or unvitalized products of disintegrated organic matter is, and is likely to remain, undecided : the question is of little importance in Preventive Medicine.

801. Epidemics are sometimes divided into *indigenous* and *imported*. All must in the first instance have arisen, and some do still arise from special conditions concurring in a particular place; but, as regards the majority of epidemic diseases, the conditions necessary for their *de novo* generation are probably so numerous and complex that their concurrence is extremely improbable; and consequently they are, as a general rule, imported. Though primary origination is rare, instances of secondary origination abound, in which the specific poison generated by a previous—perhaps remotely previous—case of an epidemic resumes activity after dormancy and sets going anew the disease which had prevailed, and spread until material favorable to its progress had been exhausted.

802. The principal epidemic diseases to be noticed in this chapter are :—*cholera, dengue, diphtheria, dysentery, enteric fever, erysipelas, measles, ophthalmia, puerperal fever* and *variola.*

803. The first and the last in this list are the most destructive in India. **Cholera** is endemic and capable of *de novo* generation in Bengal and possibly in other parts of India. Elsewhere it arises either by direct importation from without, or by the accidental liberation of its specific poison which may have remained inactive, in a dry state, for an indefinite period. This poison, whatever be its nature, exists in the characteristic evacuations, from stomach or

bowels, in a certain stage of decomposition; in which stage it may be arrested by desiccation, on the ground or the walls, on clothing or furniture, and so remain inactive until revivified by moisture. The poison may thus be brought in contact with the gastro-intestinal tract, on which it produces its specific action, setting up anew its characteristic effects, by the air we breathe, the food we eat and, most surely and destructively, by the fluid we drink. It follows that, as experience in all parts of the world testifies, cholera travels from its point of origin along the lines of human intercourse; and that its spread would be prevented by complete isolation or destruction of the excreta; in which, potentially or actually, the specific excitant of the disease exists: hence the importance of collecting with the utmost care the discharges from stomach and bowels of cholera patients with a view to their being burned or securely buried; the vacation of rooms in which such patients have lain, for efficient disinfection; the scraping of floor and walls and ceiling, with immediate burning of the scrapings and their replacement by coats of white-wash or tar; the destruction by fire, or at least the disinfection by dry or moist heat, of clothing and bedding; and the removal of the healthy from a place in the air of which poisonous material may easily be supposed to float notwithstanding every precaution.

804. The birth-place of **dengue** seems to be the West Indies; but it has occasionally appeared as an epidemic in India. Though painful it is rarely fatal. The infectious material is probably cutaneous epithelium.

805. Epidemics of **diphtheria** are rarely widely spread. Most of the cases can be traced to infection but certainly not all; whence it may be inferred that its origination without importation is not uncommon. Its exciting cause in such a case is suspected to be the poison of putrescent fæcal matter; and it is certain that its spread, when it has once been originated, is favored by the presence of such matter in the neighborhood, although cases of the disease occur in houses in whose arrangements for removal of excreta no defects can be detected. In one epidemic at least it was remarked that the disease prevailed most severely in high airy situations; in which, however, both the air and the water were contaminated by fæcal impurities. The infection of diphtheria is probably con-

veyed by the breath which has been in contact with the morbid exudation in the fauces &c.

806. Sporadic cases of **dysentery** are much more commonly met with than the epidemic form of the disease; but the latter is well known in this country. According to some authorities the affection is essentially epidemic, communicable by infection and invariably originating from a previous case. Indian experience does not confirm these views. The epidemic form of dysentery is spread by the excreta, in which a specific poison either exists or is generated by putrefaction. In all cases of dysentery, therefore, the dejections should be carefully isolated and destroyed; and the healthy should be rigidly excluded from latrines used by dysenteric patients. Fumigation of such latrines should be carefully practised after the extinction of the epidemic: and for this purpose chlorine has been specially recommended. There can be no doubt that the use of water contaminated with sewage favors the spread of, and sometimes originates, this disease.

807. Typhoid or **enteric fever** is a disease of youth, rarely occurring in persons over fifty. It is communicable by air or water which has received the specific poison from the intestinal discharges of a patient suffering from the complaint; and possibly from the cutaneous exhalations also. So far is certain. Beyond this the etiology is obscure. According to many observers the disease may originate wherever air or water is polluted with human excreta, without a pre-existing case. It must be admitted both that instances occur in which air and water continue for indefinite periods to be so polluted without an explosion of an enteric epidemic: and also that in many undoubted cases of the disease no previous sewage poisoning can be traced. There are cases also in which virulent malarious intoxication appears to produce symptoms undistinguishable from those of true enteric fever. Differences of opinion, however, as to the causation of the disease do not affect the measures to be taken to prevent its spread. Isolation of the excreta and their destruction by fire or disinfection are indispensable. The most careful search must be instituted into all the arrangements for the removal of sewage from the premises. All drains and sewers must be disinfected and cleared. The water-supply must be examined and possibility of contamination with sewage obviated.

808. It is rather in surgical wards of hospitals than in ordinary dwellings that **erysipelas** arises and spreads, wounds being the most powerful predisposing cause. Pus-cells are supposed to be the exciting cause of this eruptive disease: and it has been ascertained that they are capable of retaining their vitality for mischief in a dormant state, when dried, for an indefinite time. Isolation of the affected person is absolutely necessary to prevent the spread of this disease and the most scrupulous cleanliness of hands, clothing or instruments which may have come in contact with the patient. The freest ventilation is desirable and the epidemic rarely appears in huts or tents. Allied in some degree to this form of disease is the sloughing ulcer so frequently seen in India amongst an impoverished population. It appears to be eminently a contagious disease, and when it occurs in jails or poor-houses requires the greatest precautions for its suppression. No. epidemic poison is so difficult to remove completely from a room as that of erysipelas, and instances are on record in which all attempts at eradication have failed. Walls, floor and ceilings must be scraped; prolonged and repeated fumigations with sulphurous or nitrous acid will be necessary; and the room should be left open to free access of air as long as possible before re-occupation. The same measures are required for the prevention of the spread of hospital gangrene, or sloughing ulceration.

809. Epidemics of **measles** are rarer in India than in Europe and probably less destructive. It is stated with great confidence that the disease never arises *de novo*: but there is on the other hand some evidence in favor of the belief that the exciting cause is a fungus, growing upon damp straw. If this be well-founded the thorough disinfection by heat of straw bedding is indicated as a preventive. The affection, once established, is propagated by the discharges from the respiratory mucous membrane and by epithelium and other matters thrown off by the skin. Rooms in which cases of measles have lain must, of course, be cleansed of such morbific material by washing, scraping and disinfection.

810. Purulent **ophthalmia** is a disease to which insufficient or unsuitable food, over-crowding and defective ventilation powerfully predispose. It is transmitted by the secretion from the diseased conjunctival surfaces,

which may be received on towels or rags or sponges or the hands and so transferred to healthy eyes; or may pass through the lacrymal duct into the nostrils and thence be disseminated through the atmosphere by expiration. It has been already pointed out that pus-cells may remain dried and dormant for a long time and resume their virulence in contact with moisture. Hence the necessity of using every available means to remove dust or surfaces which may have received pus-cells from diseased conjunctivæ.

811. The expression **puerperal fever** is used very indefinitely and includes many very different morbid conditions. For our purpose it is sufficient to point out its facility of communication from one puerperal woman to others. The too frequently fatal poison may be conveyed by the hand of the midwife or the accoucheur, by an imperfectly cleaned instrument, by clothing or bedding. It is an established maxim of midwifery practice, neglect of which has produced the most unfortunate results, that a person who has been in attendance on a case of puerperal fever should, in no circumstances, approach another puerperal woman, until the most careful disinfection of the practitioner's person and clothing has been carried out and until some weeks have elapsed. Nor does attendance on puerperal fever alone disqualify temporarily for midwifery practice. The specific poisons of other epidemic diseases, especially scarlatina and erysipelas, are capable of setting up the disease. Nor is this all. It is certain that persons who dissect or make autopsies should avoid engaging in midwifery practice: and it is desirable that practising, and especially operative, surgeons should abstain from attendance on lying-in women. When a case of puerperal fever has occurred extreme care should be taken to disinfect rooms, clothing &c. &c. Clothing and bedding, indeed, should, if possible, be burned.

812. There is, in the present state of our knowledge, only one epidemic disease which is completely controllable, and by this one—**variola**—more lives are destroyed in India than by any other. It is communicated by the pus of the characteristic pustules or by a specific poison associated with this pus. One authority* has known the disease to

* Miss Nightingale.

originate, without a previous case, from insanitary conditions; but this experience has not been confirmed by other observers. The poison is not destroyed by drying, or by moderate heat; or by gaseous disinfectants, as ordinarily used: so that, as far as possible, clothing, bedding &c. which have been in contact with a small-pox patient should be burnt. Where this is not practicable, disinfection by dry heat, or by prolonged boiling with carbolic acid, should be practised. Rooms, carriages &c. should be thoroughly fumigated with sulphurous or nitrous acid; and subsequently left unoccupied, with free access of pure air, as long as possible. The best deodorant, during the progress of the disease, is iodine, suspended in the room in a small jar. With every precaution it is extremely difficult to prevent the dissemination of the disease; and unfortunately, every precaution is not always taken. It is probable that variola, as well as scarlatina and some other epidemic diseases are communicable by books and even by letters. Variola attacks horses, sheep and cattle, and perhaps other animals, as well as man; and the human subject may both impart the infection to, and receive it from, the lower animals.

813. The practice of **inoculation,** for the restriction of the ravages of small-pox, is of great antiquity in eastern countries. Its introduction into England (in 1721) was followed by a marked reduction in the mortality from variola. Thus in the ten years ending 1719, during which no inoculation was practised, deaths from small-pox in England were 31,416 per million of living; in ten years of imperfect inoculation, 1740-49, 28,282; and in the decade 1790-99, when the practice had become general, 22,863. The advantages of inoculation were that it gave an opportunity of selecting suitable conditions of place, season &c. for undergoing the disease; and that the type of the artificial affection was milder than that of natural small-pox. Thus while the mortality from the latter had been one in five cases, that from inoculated small-pox was at first one in fifty and subsequently, as methods improved, one in five hundred cases. It probably, also, conferred more complete immunity from small-pox than ordinary vaccination does. On the other hand, the practice, if it diminished the relative mortality, increased the absolute frequency of the disease; each subject inoculated being the possible starting point of a new epidemic. On the

whole it would seem that the advantages of inoculation, cautiously practised, preponderate: and it follows that it need not be forcibly suppressed in this country until we have a thoroughly efficient system of vaccination to put in its place.

814. It is probable that efficient **vaccination** is as powerful a preventive of small-pox as inoculation: it is certain that as ordinarily performed its protective power is very great, as well as its influence in modifying and moderating the variolous attack which it has failed to avert. To be efficient vaccination should produce six—never less than four—perfect vesicles; should be practised in infancy, repeated at ten to twelve years of age and again after puberty. The efficacy of vaccination in averting variola and the enormous preponderance of its certain advantages to the community over its possible dangers to the individual subject, are questions which it is unnecessary to discuss. At the present day in India the most important question connected with vaccination is Whether it should be made compulsory? Of the hygienic advantages of compulsory vaccination there can, of course, be no doubt. Of its political safety or expediency hygienists, as such, can form no opinion. It is certain that the imposition of vaccination as a preliminary qualification or a necessary operation to be undergone, has proved no bar to aspirants for admission to the army, the police, the civil departments of the public service, Government schools, or the jails.

815. Epidemic diseases being communicable from one person to another, it is evident that their spread will be restricted by whatever means impedes communication between the sick and the healthy. In theory, therefore, **quarantine** would be an effectual check upon the propagation of epidemics. It would not extirpate them, because they are communicable otherwise than by personal proximity, in ways over which quarantine exercises no control; but it would considerably reduce the chances of infection. It is, however, better, in many cases, to submit to the chance of the introduction of disease into an uninfected locality, than to undergo the serious interruption of intercourse and other inconveniences which thoroughly effective quarantine would cause. Again, the cost and difficulty of making quarantine thoroughly effective are

enormous. We may, therefore, abstain from attempting to exclude epidemics from open towns or villages by a *cordon sanitaire*. With walled towns something may be done by inspection at the gates and detention of suspicious cases in extra-mural hospitals: but these duties should be very carefully performed, with the least possible interruption to intercourse and trade. Cases of infectious disease can readily be excluded from barracks, and the lines of sepoys and police; but it is neither possible nor desirable to confine the men to their quarters during the prevalence of an epidemic in the neighborhood. With jails more may be done, especially if labor is altogether intra-mural: and during the prevalence of serious epidemic disease in a district, quarantine, of ten days at least, should be imposed upon new admissions. Ships on board of which cases of cholera or small-pox have occurred should be boarded on arrival at port by a medical officer, and disinfected under his superintendence. If any sick of these diseases remain on board they should be landed and detained in isolated hospitals until they have passed the stage in which they are capable of communicating infection. In general, it is to be borne in mind that quarantine is not useless because it cannot be made absolutely complete; that something is gained if only one possible source of infection gains access to an uninfected place instead of two or more; that the real objection to quarantine is not its inefficacy but its interference with human intercourse; and that the propriety of its enforcement in any particular case is to be decided on by considering on the one hand the inconvenience and expense, and on the other the degree of completeness, and the proportional amount of benefit, attainable.

816. Epizootics in the lower animals correspond to epidemics in the human population; being diseases communicable by contagion or infection, from one diseased animal to others of the same species, in some cases to others of different species. One of them, glanders, is certainly and others are possibly, capable of transfer to man.

817. The general preventive of attacks of epizootic disease is attention to the sanitary condition of flocks and herds. Cattle of all kinds should be sheltered from heavy rain, from excessive heat by day and cold winds by night. Their sheds should have floors raised above the soil;

paved or tiled, so as to be readily scraped and cleaned, and sloped for drainage. Ventilation should be attended to on the same principles as for human dwellings, and light should not be excluded. The shed and its neighborhood should be kept perfectly clean, the dung and urine being daily removed from the premises. The animals should be fed, not merely allowed to wander about in search of precarious and scanty pasture: and should be supplied with clean water for drink. They should be kept from lands under water or recently inundated or ill-drained. Thus treated they will be much less liable to attacks of epizootic or other disease and, if attacked, will be less likely to succumb.

818. The **principal** epizootic diseases to be noticed are; —*rinderpest, anthrax, foot-and-mouth disease, and pleuro-pneumonia* in horned cattle; and *glanders* in horses. To the first two of these most of the mortality in this Presidency is due. Pleuro-pneumonia prevails in the North-West Provinces, the Punjab, Sindh and some parts of Bombay, but is comparatively rare in Madras.

819. The formidable nature of **rinderpest** is shown by the fact that in the ten months, from 1st April 1874 to 31st January 1875, 32,947 cases of the disease were reported in Madras with a mortality of 585·33 per mille. It appears to be capable of origination *de novo* and, once generated, is communicable with the most deadly facility; its period of incubation ranging from 24 to 72 hours. Its specific poison affects principally the digestive mucous membrane, especially that of the abomasum. It has been supposed by some to be akin to variola, and both inoculation and vaccination have been suggested as preventives. Its earliest symptom is a spasmodic twitching of the muscles of the chest and neck, and sometimes of the hind-quarters; which resembles but is different from the accompanying or following rigor. The temperature rises to 105° F., subsequently falling as low as 88°. The pulse is little disturbed at first but afterwards becomes quick and weak. The respiration is accelerated; and labored when the respiratory muscles are involved in the spasm. The disease may last from one to sixteen days, its usual duration being from three to nine.

820. In this, as in other epizootics, **isolation** and **cleanliness** are indispensable to the prevention of its spread.

The healthy animals must be removed from the village to a distance of not less than 300 yards; and divided into herds of 20, separated by not less than 200 yards. The sick will remain in the village for treatment and no communication between diseased and sound must take place. All excreta of the sick should be burnt: all corpses deeply buried. The hides should be scarified before burial: or, if allowed to be removed, should be tanned immediately; or, at least, exposed to sunshine for three weeks, in a space so enclosed that healthy cattle can have no access to it. The sheds should be daily cleaned and sprinkled with carbolic solution, 1 part in 60 of water; a weaker solution 1 in 100, being thrown freely about the yard, until its odor is strongly apparent. Walls and floors of buildings where diseased beasts have lain should be scraped and limewashed, and the scrapings burnt. Fumigations with sulphurous acid will also be useful. *

821. Splenic apoplexy, black-quarter, congestive fever, malignant sore-throat, inflammatory fever &c. &c. are synonyms of a blood-disease most conveniently termed **anthrax.** In India it is certainly communicable, not only to healthy cattle but to man; but in colder climates it is not regarded as a contagious or infectious disease. In this Presidency the mortality during the epizootic of 1874-75 was 742·41 per mille. It appears to arise spontaneously when cattle are transferred from poor and scanty pasturage to rich herbage, or when they are permitted to graze on marshy or recently inundated lands. When the days are hot and the nights cold, and the animals are unsheltered, the predisposition is increased. The young and most thriving, and especially those which are improving after previous low condition, are the most susceptible. The characteristic symptom (which frequently appears first at night), is the formation of puffy, crackling swellings under the skin, generally of the loins or extremities; or mucous membrane of the tongue or fauces—the disease when occupying the last position being often termed "malignant sore-throat." Temperature is raised, respiration and circulation are hurried. Death supervenes in from 2 to 9 hours,

* Sheep and goats are capable of being infected with rinderpest, but less so than cattle. They may convey the disease without catching it themselves.

though some cases linger for 24. The disease, once originated, being readily communicable, the precautions as to cleanliness and isolation described above are essential. In Europe sheep are liable to this disease which, as affecting them, is popularly called **braxy.**

822. Epizootic aphtha, commonly called **foot-and-mouth disease,** is not largely destructive of life in this country; the mortality rarely exceeding 3 per cent. here, though it rises to 50 in Europe. It is amenable to treatment and with care the mortality might be reduced almost to nothing. It is an eruptive fever, characterized by vesicles on the mucous membrane of the mouth or on the feet or on both. They appear sometimes also on the udder. Sheep, goats, pigs and poultry are liable to the disease; and it is said to have been conveyed, by means of the milk of affected cows, to the human subject. It is generally due to contact or vicinity with a previous case, the incubative period being in most instances 36 hours; but it is supposed to be capable of spontaneous origination when the cattle-shed or the ground is allowed to remain fouled with dung and urine. The absence of purging and the affection of the feet distinguish this disease from rinderpest: but both maladies may co-exist in the same animal.

823. As already mentioned, **pleuro-pneumonia** is rare in this part of India. Its name sufficiently indicates its nature; but it differs from the human disease in being communicable. It is not known to originate except from a previous case, and herds kept isolated from other cattle are not attacked. Its period of incubation is probably from four to six weeks. Death often occurs in a week or ten days; but in some fatal cases life is prolonged for two to six months. Inoculation of healthy animals with matter taken from the lungs of those which had died of this disease was at one time recommended, with a view to inducing a milder attack: but the experiments were not successful.

824. Only one equine epizootic will be mentioned, namely, **glanders**; to which the horse, ass and mule are liable and which is communicable, not only to these animals but to the human subject. When the specific poison affects principally the air-passages, the disease is termed glanders; when the skin, areolar tissue, and lymphatics are attacked, it is called **farcy.** The former is rapid and

violent in its course, which invariably terminates in death. Its characteristic symptoms are the abundant discharge, sometimes bloody or purulent, from the nostrils; and the eruption of small painful lenticular tumors, chiefly on the nostrils, neck, and shoulders. In farcy the same eruption occurs; the limbs are swollen; and the symptoms generally are less severe. Damp ill-ventilated stables, improper food, excessive fatigue and other depressants of health predispose to the reception of the specific poison; the principal vehicle for which is the discharge from the nostrils. This, forcibly ejected in fine spray, may infect stables, food, litter, vessels, &c., &c. and so communicate the disease to healthy animals. A beast suffering from glanders should be immediately killed and everything possible done to destroy the specific poison which it has generated, as in the case of rinderpest.

CHAPTER XII.

SANITARY LAW.

825. Sanitary legislation has not been very active in India, and much of what has been done in this direction is rather permissive than obligatory. A beginning, however, has been made; and, if the laws which have been enacted were enforced, the sanitary condition of the country and the people would be considerably improved. Besides a few sections of the *Penal Code*, it will be sufficient to notice the provisions relating to sanitation contained in the *Municipal* and *Local Fund Board* Acts; and the law and rules at present in force as to *Quarantine.*

826. The fourteenth Chapter of the **Penal Code** is the one which contains the sections relating to public health. It starts by defining a *public nuisance* to be that "which causes any common injury, danger, or annoyance to the public or to the people in general who dwell or occupy property in the vicinity, or which must necessarily cause injury, obstruction, danger, or annoyance to persons who may have occasion to use any public right:" and Sections 290 and 291 provide punishment by fine for the committal of a public nuisance, and by imprisonment or fine or both for repetition or continuance of the offence after injunction to desist by lawful authority. Sections 269 and 270 provide punishment with imprisonment or fine or both for unlawfully or negligently or malignantly doing anything which a person knows or has reason to believe to be "likely to spread the *infection* of any disease dangerous to life."* It appears clear that the practice of *inoculation* is not made penal by these sections. In Section 278 rendering the *air* noxious to the health is made punishable by fine; in 277, voluntarily fouling *water* "so as to render it less fit for the purpose for which it is ordinarily used" is made punishable with fine or imprisonment or both. In

---

* During epidemics of small-pox persons in every stage of the disease may be seen in the streets of Madras and other towns.

273, exposing for sale with guilty knowledge articles of *food* or drink which have been rendered or have become noxious, or are in a state unfit for food or drink: and, in 272, *adulteration* of food or drink, so as to make it noxious, with intent to sell and knowledge that it is likely to be sold as food or drink, are made punishable with fine or imprisonment or both. Lastly, similar punishment is provided, in Section 271, for disobedience to rules promulgated by the Government of India, or by local Governments, with reference to *Quarantine.*

827. The Madras Act III of 1871, the Towns' Improvement Act, is that under which Mofussil **Municipalities** are worked in this Presidency. The latest Act applying to the Municipal Commission of Madras City is Act V of 1878. The sanitary provisions in these laws, especially in the latter, are excellent and need only enforcement to be productive of much benefit to the health of the people. Unfortunately, while the things which Municipalities "shall" do in providing police, education, and even hospitals, must be done, little pressure is exerted in order to ensure the adoption of measures necessary for the prevention of disease. An enlightened Vice-President can improve enormously the sanitary condition of his town: while one ignorant or careless of the laws of health may neglect every sanitary precaution, except perhaps the sweeping of the streets, and disregard the suggestions of sanitary officers with impunity.* The following paragraphs show briefly what powers for the protection of health these Acts confer. The **Local Funds** Act (IV of 1871) contains no sanitary sections and confers no special powers for sanitary purposes, except that it vests in the Boards all public markets, tanks, and wells, and requires them to make due provision for vaccination. Great improvements, nevertheless, can be effected by these Boards, in the cleanliness and the water-supply of non-municipal towns and villages; and in some districts, where the presiding officers have been interested in sanitation a great deal has been done.

A Vice-President of the Municipal Commission of a large and densely populated town remarked once, "I agree with X" (the President), "I don't believe in sanitation." It is scarcely necessary to add that the state of that town, from a sanitary point of view, is deplorable.

828. Taking the sanitary provisions of the Municipal Acts in the order of subjects adopted in the early chapters of this Manual, we find the following provisions directed to the preservation of the purity of the air.* In Madras new *streets* cannot be laid out without the President's approval of the plans (B 234—238); and that officer is empowered (B 314) to remove, if necessary, any block of buildings the existence of which he considers, through crowding or want of drainage or ventilation, to be dangerous to the health of the inhabitants of the neighbourhood. The owners or occupiers of houses, buildings, or land within municipal limits are liable to fine for permitting the same to be in a filthy or unwholesome state (A 104, B 312); or, in Madras, "overgrown with noxious vegetation." The Commissioners "may" provide dust-boxes in the streets and "may" require dirt and rubbish to be deposited in them "daily or otherwise periodically;" and, if they avail themselves of these permissions, persons depositing dirt in the street, except in these receptacles, are punishable with fine (A 99). In the Madras Act (B 299) "shall" takes the place of "may." "Committing nuisance" or otherwise depositing filth or refuse on streets &c., is punishable by fine (A 100, B 298). Owners and occupiers are required to keep *hedges* bordering streets or roads cut to a height not exceeding six feet (A 149), (seven feet, B 320); and to remove "noxious vegetation" (A 150). Commissions "shall" provide public *latrines*, in sufficient numbers and in proper situations (A 105), (B 310); and, in Madras, owners and occupiers "of every building, to which land of an area exceeding eight grounds is attached," shall provide latrines for servants &c., (B 272) under penalty of heavy fines. *Cart-stands* must be licensed (A 136); and also, in Madras, places where horses, horned cattle, sheep or goats are kept in considerable numbers (B 325), while *swine* are not to be kept "in or near any street, so as in the opinion of the President to be a nuisance." (B 326). *Offensive trades* may not be carried on, within limits to be fixed by the Commissioners, without their license (A 129), (B 322): and provision is made for

---

* The figures in these paragraphs are the numbers of the Sections in the Acts: A being the Towns' Improvement Act, and B the City of Madras Municipal Act, 1878.

the removal of offensive works which may have been in operation before the Acts came into force (A 132, B 324).

829. All public sources of **water-supply** are under the control of the Commissioners, who have power to set apart certain tanks &c., for special uses; persons using them for other than the assigned purposes being liable to fine (A 114—116, B 214, 221, 225). They can compel private owners of tanks to keep them clean; and to empty pools of stagnant water likely to be injurious to health (A 117). In Madras the Commissioners are bound to "provide a supply of drinking-water within the City" (B 211).

830. In connexion with air and water the provisions relating to disposal of the **dead** may be mentioned. No burial or burning ground can be formed without the license of the Commissioners (A 133, B 360); and the use of unlicensed grounds is punishable by fine (*Ib.*, B 362). They have power to close burial or burning grounds which are injurious to health; the use of grounds so closed being punishable by fine (A 134, B 365, 366). They are empowered to provide a sufficient number of convenient places for burial or burning (A 135, B 368). No further provisions on this subject are made in the Towns' Improvement Act: but in the Madras Municipal Act, Sections 356–369, stringent rules are laid down. Burial or burning in any unregistered place; or burial in any place of public worship (with a certain exception), or at a less depth than five feet or at a distance of less than two feet from another grave; re-opening of a grave without the President's written permission or a Coroner's or Magistrate's order; keeping a corpse in a burning-ground for more than six hours without beginning cremation; imperfect cremation of the body or the clothing; exposure of the corpse, or laying it down in, a street; and removing "otherwise than in a closed receptacle any corpse or portion of a corpse kept or used for the purpose of dissection," are offences punishable by fine.

831. The provisions relating to **food** are A 123–127 and B 332–337, 341 (*c*). By these sections Municipalities may (in Madras shall) provide slaughter-houses; all slaughter-houses must be licensed; no animal is to be slaughtered or skinned &c., except in a licensed place; provisions unfit for human food are to be seized and

destroyed, the owner being liable to fine; and (in Madras) "whoever shall feed or permit to be fed, any animal with night-soil, dung, or stable refuse shall be liable to a fine."

832. The Madras Act (B 315) empowers the President to take proceedings before a magistrate, with a view to the punishment of persons permitting the overcrowding of **dwellings**; and Sections 257–271 give him control over the drainage, sewerage, and general conservancy of all houses within municipal limits. Similar but less extensive powers are conferred upon other municipalities.

833. All municipalities are required to make provision for the **registration** of births and deaths. Failure to notify the occurrence of a birth (within one week in Madras or twenty days elsewhere) or a death (forthwith in Madras, within twenty days in other municipal towns) to a registrar is punishable by fine: the duty in the former case devolving upon the "father or mother * * * or, in case of the death, illness, absence, or inability of the father or mother," upon "some person who was present at or in attendance during the child-birth" (A 92, B 374); and, in the case of a death, on "some one of the persons present" (A 93, B 375).

834. Commissioners are empowered to make **bye-laws** "for the management of all matters connected with conservancy" (A 163): and "to affix fines and penalties for the infringement" thereof: the fines being limited in amount. In the Madras Act, Sections 389–394, the subject matter of bye-laws and the rules relating to them are more fully detailed.

835. The duties of the **police** in connexion with these Acts are very clearly laid down. "Any police constable or officer" can arrest, without warrant, any person guilty of any offence committed within his view against any provision of this Act, or any bye-law under this Act," (A 154); and "it shall be the duty of all police officers to give immediate information to the Commissioners of any offence committed contrary to the provisions of this Act" (A 155). B 431 corresponds to the latter section, adding "and to help them in giving effect to the provisions of this Act." B 432 enacts that "any police officer may arrest any person committing nuisance &c., if the name and address of such person be unknown to him, and if

such person decline to give his name and address, or if the police officer shall have reason to doubt the accuracy of such name and address if given; and such person may be detained at the station-house until his name and address shall be correctly ascertained." It is to be feared that these provisions of the Municipal Acts are not always fully borne in mind.

836. Act No. I of 1870 of the Government of India empowers the Governor-General in Council, and Local Governments with his previous sanction, to make rules for **quarantine**. The rules are to provide (1) for putting any vessel into a state of quarantine; (2) for regulating the intercourse of vessels in a state of quarantine with the shore, or with other vessels; and (3) for regulating the intercourse between ports when an infectious disease prevails and other ports. Such rules officially published in gazettes "shall thereupon be deemed to be rules made and promulgated under Section 271 of the Indian Penal Code."

837. The **rules** now in force will be found as appendices to a Resolution of the Government of India, dated Simla, 9th May 1879, No. 3—95-100 (*Proceedings of the Government of Madras, Marine Department*, 24*th May* 1879, *No.* 280). They are based on "two leading principles;—*first*, that a system of medical inspection is sufficient to meet the case of all vessels arriving with persons suffering from any disease which is endemic in this country; and *secondly*, that quarantine should be reserved for occasions where there is danger of diseases being imported, which are either unknown or not commonly rife in India—such, for example, as plague or yellow fever." The Medical Inspection Rules (Appendix A) "are intended for every-day use." The Quarantine Rules (Appendix B) "will only be brought into operation very occasionally with sanction of the Government of India, which must previously be obtained in each case. Such sanction will be given only in the case of plague, yellow fever, or some fatal epidemic not ordinarily prevalent among Indian populations."

CHAPTER XIII.

STATISTICS.

838. **Statistics** are the numerical expression of collected facts and their relations. They represent the results of simple *enumeration*, as the population of a given area; the *ratio* of two totals, as of male to female births; or *means* deduced from two or more numbers or series of numbers. Their value depends primarily on the care with which enumeration has been performed, ensuring the inclusion of all the individual members which possess, and the omission of all which want, the differentiating character of the group. In the preparation of sanitary statistics, especially, owing to the complexity both of causes and effects, accurate discrimination of particulars and skilful grouping according to essential characters are indispensable.

839. The **use** of statistics, for our purpose, is to furnish indications of the success or failure, and the degree of either, of hygienic measures, therapeutical or preventive; and to ascertain the various effects on the health of men and the lower animals of differences in climate and other natural causes as well as of differences in the circumstances which are under our control, as food, clothing and habits of life. In using statistics for the deduction of conclusions and rules for practice even greater caution is necessary than in their preparation; and the suspicion with which they are often regarded is more frequently due to unscientific inference than to untrustworthy numerical premises. The errors most likely to be committed and most carefully to be avoided are the founding of a general conclusion upon an insufficient number of particulars, and comparing series of effects which, resulting from different combinations of causes, are not strictly comparable. A common example of the former is the attempted establishment of a certain line of treatment upon a few successful cases. Comparing the mortality in a regiment during a period of profound peace with that

during an equal period of active service is an illustration of the latter.*

840. The relation of **two numbers** is expressed either by reducing the smaller to unity and the larger in proportion; or by representing one as so much per cent., per mille or per 10,000 of the other. In the former case both numbers are divided by the smaller; in the latter the number (whether smaller or greater) which is to be expressed as so much per cent., per mille or per 10,000 of the other is to be increased by adding two, three or four cyphers and divided by the other. For example, of the European population of this Presidency numbering (in 1871) 14,561, 4,604 were females; that is, either 1 in (14,561 ÷ 4,604 =) 3·16; or (460,400 ÷ 14,561 =) 31·62 per cent. The latter method is preferable for scientific purposes, but the former probably conveys a more distinct idea to the general reader. The prevalence of color-blindness, for instance is more vividly presented by saying that 1 male in 20 suffers from it than by stating that 5 per cent. of the male population are so affected.

841. When the results of two or more enumerations, either of totals (as the numbers of births in a Lying-in Hospital in the several months of a series of years) or of ratios (as the annual percentages of deaths to strength in a regiment during a decennial period) are to be compared, **means** must be employed. A mean of a series of numbers is one lying between the greatest and least, and having a definite dependence on all. Of several kinds of mean, two only are important in sanitary statistics—the *arithmetic* and the *quadratic*. The former is so related to the numbers of the series, that the sum of the differences between it and those which are greater than it is equal to the sum of the differences between it and those that are less; and it is the quotient of the sum of the series by the number of its members. The quadratic mean is the square root of the arithmetic mean of the squares of the given numbers. It always (unless when all the numbers

* The notorious '69 per 1,000' represented by a commission in England to be the death-rate of the European Army in the pre-Nightingale era in India, deduced from a long series of years during which not only utter ignorance of sanitary science prevailed but most sanguinary wars occurred, and compared with subsequent short periods of unbroken peace, is a melancholy case in point.

of the series are the same) exceeds the arithmetic mean; the excess being proportional to the inequality of the members of the series, so that the two approach more nearly to coincidence as the numbers approximate to equality.

842. The **arithmetic mean** is used either as a true average of a series of definite numbers; or to represent the probable value of a fixed quantity, or the probable value of a variable quantity estimated in its mean condition. In the first case the numbers from which it is deduced are exact, and, if not absolutely independent of each other, their dependence is not taken into consideration. Daily mean temperature, obtained from hourly observations, is an example (if we assume that each observation represents the average hourly temperature); and, as the mean temperature of one day may exceed that of another, although no part of the former was hotter than the hottest part of the latter, so, in general, excess of means does not imply excess of extremes. Again, if the average age of a number of persons be x, this does not imply that the age of any one of the group is x, or that the ages of the majority approximate to x; but only that the sum of the differences between x and the greater ages is equal to the sum of the differences between x and the less. And, if we compare this group with a second whose average is y, a number less than x, it may not be concluded that any member of the first group is older than every member of the second; it is only certain that the aggregate ages of the two groups are in the ratio $x : y$.

843. In this case we had to deal with two or more numbers of definite value; in the next we obtain a single number representing the **probable** value of a **definite** quantity. For instance in determining the dew-point by a hygrometer, each of our observations being inexact, we take the mean of several as more likely to be correct than any one; and we consider its approximation to absolute truth proportional to the number of observations from which it has been deduced. In general, when two conditions are of frequent occurrence, and there is no reason why one should happen oftener than the other, the probability of their occurring with equal frequency approaches certainty as the number of observations is increased.

844. In this second case the value of the mean as a representation of the truth depends on two conditions, namely, that the error in one direction is probably equal to that in the other, and that the number of observations or other data is sufficient.* If these conditions could be known to be fulfilled the result might be taken as true; but, as this degree of certainty is unattainable, a standard is necessary by which the value of the mean may be estimated, especially when the means of different groups of numbers are compared. The most important methods which have been suggested are that of *successive means*, that of the *mean error* and *Poisson's formula*.

845. Having made an indefinite number of determinations, to three places of decimals, of the quantity whose probable value it is desired to estimate, assuming that the errors in one direction are *quam proximé* equal to those in the other, we take the **successive means** of the first two, the first three, the first four numbers, and so on, to about four places of decimals. The first means will probably agree in their whole numbers; and, as the process is continued, coincidence of the successive means in the first, in the second, in the third, and ultimately in the fourth, decimal place will be attained; the accuracy of the mean increasing with the number of concurring figures. When the point is reached at which the whole numbers and four places of decimals are constant in successive processes we shall be justified in accepting the figures as absolutely accurate. Without carrying out the calculation to this degree of accuracy we learn by this method how many determinations of the variable value of a fixed quantity are necessary to ensure accuracy in the mean, to any extent depending on the nature of the inquiry; that is, to whole numbers only or to any desired number of decimal places; or if the estimations are necessarily few we have a test of the degree to which the general mean may be relied upon as accurate. In employing this method care must be taken that the number of latest successive means used for establishing the final figure, is sufficient to exclude the possibility of merely accidental concurrence.

846. The rule for deducing a correct mean by this method is;—take the figures in which the successive means agree as certain and the arithmetic means of the first series of non-concurrent figures will give the next

figure. The measure of uncertainty will be the greatest difference between the mean so obtained and the given series of numbers.

847. As the value of a series of observations or determinations depends upon the amount of error involved, the latter affords a measure of the former. The **mean error** is the *quadratic* mean of all the deviations of the observed values from the calculated arithmetic mean, and we judge one series of observations to be better than another in proportion as its mean error is less. The quadratic mean is used because, as squares are positive, positive and negative errors have equal weight in determining the mean error; and, secondly, because quadratic means increase with the inequality of the determined values (841), which has no effect upon arithmetic means. Two series of observations, in one of which the errors were more unequal, that is more important, than in the other might yield the same arithmetic mean, but would differ in value; the former being farther from certainty than the latter. This inferiority is expressed by its higher quadratic mean error, while the arithmetic mean error might be the same for both.

848. **Poisson's formula** is intended to show the limits of error involved in taking the relation of a sub-division of a group to the group itself to represent accurately a similar relation in other cases. Based (as all such mathematical formulæ must be) upon an arbitrary assumption it is not to be accepted as absolutely true; and it is evident that if applied to the true mean it would still give limits of error. It is useful, however, as indicating where a number of observations is wholly insufficient to support an inference. If $\mu =$ total number of cases, $m =$ one group and $n =$ another, into which they are divided. The ratio of each of the sub-divisions to the whole is $\frac{m}{\mu}$ and $\frac{n}{\mu}$. In a second series the value of the *former* lies between the limits $\frac{m}{\mu} \pm \sqrt{\frac{2mn}{\mu^3}}$ from which, if we assume it to be approximately true, it follows that the greater the number of cases observed in the first instance the safer will be the inference to a second group; because increase of μ diminishes the value of possible error.*

849. In the third case, the arithmetic mean is taken as the probable value of a **variable** quantity under mean conditions; as for example the mean daily temperature of evaporation, which fluctuates under the influence of external conditions and is also liable to errors arising from imperfect observation. In the absence of the latter we should have a pure average; but, errors of determination

* For example, by treating 300 cases of pneumonia in a certain way there were 30 deaths and 270 recoveries, or a mortality of 10 per cent. By this rule, however, we find that with this treatment we may have an average mortality of only 5·1 per cent., or as much as 14·9 per cent.

being inevitable, the mean represents only the probable value of the average; and (if extreme accuracy were required) the conditions described above should be fulfilled.

850. In **comparing means** of different series it is necessary to have some test by which to judge whether the arithmetic means, ascertained, in the manner above described, to approximate to the averages, may be used for comparison. If the series are *complete*, that is if the observations have been sufficiently numerous to justify a conclusion, founded on the successive means, that irregularities have probably neutralized each other, the following rule (laid down by Radicke) may be applied, viz.;—that the difference between the means must be greater than double the largest fluctuation. If, for example, it is desired to show that the death-rate of prisoners has diminished in consequence of an improved dietary. Supposing two decennial periods to be compared, the excess of the former average mortality over the latter must be more than twice the greatest difference between either mean and the ten numbers from which it has been deduced.

851. In dealing with **incomplete** series of observations it must be remembered that the degree of accuracy obtainable is necessarily low, owing to the possible intervention of disturbing causes, the effect of which the number of observations is insufficient to eliminate. Such an agency may not produce its full effect at once, nor may the effect cease immediately after it has ceased to act directly; or its occurrence may be periodic. Thus, in the example given above, if the death-rates of one year before and one year after a change in dietary be compared, no conclusion as to the effect of the alteration could justifiably be drawn. A draft of prisoners withdrawn for transportation in the second period may by reducing excessive numbers improve health; or epidemic small-pox may attack the prisoners in one year only; or in both, but with less intensity in the second as its virulence dies out. Such series, therefore, require special examination before they can be taken even provisionally as complete. The first step is to take a double series of successive means in each group, one ordinary the other reversed, that is, beginning at the last term; and to note whether the fluctuations in either series are greater in the latter half than in the former. If they be, the

numbers are valueless for comparison. If not, the series may be treated as described in the last paragraph; that is, we must examine whether the difference between the means exceeds twice the largest fluctuation; that is, twice the difference between either mean and the observation most divergent from it.

852. In general, when comparing two series of numbers representing the effects of many combined causes, with a view to determining whether the preponderance of one of the two means is the result of a cause present in one case and absent in the other, we can never decide with absolute certainty whether the preponderance is due to the unneutralized portion of disturbing causes common to both or to the agency of the cause known to be confined to one. A variable degree of probability is, however, obtainable. The greater the difference between the means in proportion to the importance of the common disturbing causes, as measured by the divergences of the numbers in each series from its mean, the greater is the probability that the preponderance is due to the special cause entirely or partially. The problem is to determine the least difference between the means, in comparison with the fluctuation, which will fairly justify the conclusion that the preponderance is the effect of the particular cause. An arbitrary assumption of some kind must be made and Radicke's rule involves one which confers upon conclusions which it sanctions a high degree of probability.

853. In collecting statistics it is well to note **extremes** as well as means; the latter represent probabilities, the former possibilities. Sometimes comparison between the mean of the extremes and the general mean is useful as throwing light on the value of the latter; as, for instance, in comparing the mean duration of life in two classes. Of extremes, in even a greater degree than of means, it is true that inference from one group of facts to another is safe in proportion to the number of observations.

854. In **sanitary statistics** more than in any other, multiplication of observations, variations of experiment, elimination of unessential conditions, accuracy of classification and the utmost caution in inference are required. Such is the complexity of causes, conditions and effects in all matters relating to health that even facts collected through long periods and grouped with skill rarely justify

more than probable conclusions; while the consequences of mistaking probability for certainty may be, and have been, disastrous.

855. Assuming accurate periodical enumerations and a tolerably perfect system of registration of births and deaths, the following are the **chief points** with which hygienists are concerned;—mean annual *variation* of population, ratio of *births, sickness* and *deaths* to *population, mean age at death, expectation of life, mean duration of life* and *probable duration of life.*

856. The rate at which a population **varies** depends upon the numbers of births and immigrants on the one hand and of deaths and emigrants on the other. Naturally and generally the increment preponderates; and the reverse condition, unless explicable by emigration due to over-population, betokens an unfavorable sanitary state. The actual population at any time subsequent to an enumeration can be ascertained, in order to know the rate of sickness or mortality, only from the variation. When births, deaths and migrations are accurately registered the true variation can be calculated, which added to the result of the latest census will give the actual population; but in other cases an approximation only can be made by dividing the difference between two successive census-totals by the number of years (or months) that have intervened and taking the quotient as the annual (or monthly) variation. As, however, population increases in geometrical, not, as this calculation implies, in arithmetical progression, the result is not accurate, diverging from the truth in proportion to the time which has elapsed since last enumeration. In hospitals, regiments, jails &c., where the actual population is known from day to day, the variation is unimportant.*

857. The ratio of **births to population,** depending upon accurate registration of the former, can, rarely in Europe

* In England and Wales the increase of population between 1861 and 1871 was 13·19 per cent. This rate was higher than that of any previous decade, and much of the increase was probably due to immigration. The population of Scotland increased 9·7 per cent. during the same period; that of Ireland diminished 6·7 per cent. The annual rate of increase of population in England and Wales, during the first seventy years of the century averaged 1·35 per cent. The population would double itself in fifty-two years at the rate of increase which has prevailed during the present century.

and still more rarely in India, be ascertained. Besides the total number of births, registration should record sex,* live or still-birth, whether premature or at full term; in order that the proportions of these to the total births and to the whole population may be known.

858. It is useless to expect information in this country on the ratio of **sickness to population**, generally: but it would supply the best test of the progress of sanitary improvement. The number of persons constantly sick in a community, grouped according to sex, age, occupation, nature and duration of disease, should be ascertained and stated per mille or per myriad.†

859. **Deaths to population**, similarly stated, gives a rough means of estimating sanitary condition. Deaths should be registered according to sex, age and disease, and grouped in quinquennial periods as regards the second with an additional class of those dying within one year of birth. The mille or myriad should be the number of persons living at the beginning of the period—a year, for instance—for which the mortality is estimated, *plus* a number representing the mean duration of life, during the period, of those born subsequently. A child living six months within the year for instance, would add 0·5 to the population with which the year began.‡ The following formula is used for calculating the annual death-rate (A) from one quarter's returns;—

$$A = \frac{365240\, d}{p\, q}$$

q being number of days in the quarter, p the population and d the number of deaths.

860. In using the **death-rate as a test** of sanitary condition it must be borne in mind that each year of life has

* In England the male births are to female as 104,811 to 100,000; though in the living of all ages males are to females as 100·029 to 100·000.

† In England and Wales the ratio of constantly sick is 44 per 1,000.

‡ The general mortality for England and Wales is 22·36 per 1,000; the proportion of the sexes dying being 103 males to 100 females. The male death-rate is 23·15, the female 21·58. The mortality of the healthiest districts ranges from 15 to 17, of the unhealthiest from 26 to 30 per 1,000.

its specific mortality and that, consequently, the death-rate varies with the ages of the population. If, for example, the proportion of young children in the community be high, the total mortality will be exaggerated. This is, however, a better test than the mean age at death. On the whole, the death-rate affords, though not the best, the most convenient test of the health of a population; and in this country we cannot hope for any better.

861. The **mean age at death**, or mean life-time, or expectation of life at birth, is the sum of the ages of all persons dying within a given period divided by the number of persons. As has been mentioned above, it does not yield satisfactory information as to the comparative health of a class or community. Large infant mortality, for instance, would reduce it disproportionately. It is, however, applicable to certain cases. If the lives of a large number of persons born in a given year be traced and the sum of their ages at death be divided by the total, the result will give a good idea of the sanitary condition by comparison with a group similarly treated in another country or class. Or, in two stationary populations, the mean age at death of all who die during the same term of years will give a fair estimate of comparative sanitary condition. In general the test will only be a true one when the blanks made by deaths are filled by new members of the class entering at the same ages as those of the deceased at the time of their entrance. It is, therefore, fairly applicable to soldiers whose age at enlistment is tolerably uniform.

862. There are three cases in which the mean life-time is altogether **inapplicable** as a test of sanitary condition. Firstly, it should not be used in comparing one nation with another during the same period, or with itself during different periods; because the constituents of the populations may vary considerably even in a few years. In a certain year, for example, the population of England included 46 per cent. of inhabitants under 20 years of age and the United States 54 per cent.; tending to make the mean age at death in England greater than that in the U. S., independently of all sanitary conditions. Again, in England, the population under 20 was 49 per cent. in 1821 and 46 per cent. in 1841, giving a higher mean age at death at the latter date. Such differences in populations affect the mean age at death so as to render it useless as a test of health in the cases indicated. Two populations subject to the same causes of mortality and losing the same number of persons by death at the same ages may have very different mean life-times.

863. **Secondly**, in comparing the health-states of two districts, urban or rural, so many other considerations are involved besides the insalubrity of the localities, affecting the composition of the population with regard to age &c., that this is worthless for the purpose.*

* The fallacy of this test is shown by comparing Liverpool with Suffolk. The former has only 42 per cent. of population under 20 while the latter has 47; tending to equalize the mean age at death in the two places, although the sanitary conditions are so widely different.

864. Thirdly, it is inapplicable to comparisons of healthfulness of different employments or different social positions, without regard to places of residence, unless discrimination is used to avoid error. If the earliest age be the same in the groups compared, if they have received no rapid accession of numbers during the period under consideration, and if all the deaths are recorded, the mean age at death will give a fair basis for comparison. But if two occupations are compared which have different ages of entry, or if one is stationary while the other is increasing rapidly in numbers, or if the entire group is considered in one case and only the older or younger members in the other, the test is inapplicable.

865. The **expectation of life**, or mean future life-time, is the mean number of years which, in a given community, a person of any age may hope to live. Life-tables, which contain the results of experience on this point, are based on the numbers and ages of the living and the number and ages of the dying. This is the most valuable test of health-state.

866. The **mean duration of life** or mean life is the sum of the age and the expectation of life. Being based on an enumeration of all the deaths after a given age occurring in a community whose members have been followed through their lives it is a more valuable test than the mean age at death, which is founded only on such deaths as happen to be registered in a population fluctuating in numbers by births and migration as well as deaths.

867. The **probable duration of life** or probable life-time, or equation of life, is the age at which of a number of children entering the world one-half will die, so as to render the chance of any one of them dying before or after that age an even one. For example if, of 51,274 males and 48,726 females, 25,637 of the former die between the 45th and 46th years, and of the latter 24,363 die between the 47th and 48th years, the probable duration of life for males will be $46\frac{1}{2}$ years, and for females $47\frac{1}{2}$.

868. The effects of **marriage** upon health have been deduced by Bertillon from official statistics obtained in France, Belgium and Holland. They are favorable. Of *men*, from 25 to 30 years of age, the married gave 6, bachelors 10, widowers 22 deaths per 1,000; from 30 to 35 the numbers were 7, 11 and 19; from 35 to 40, 7·5, 13·0 and 17·5. Very early marriages, however, are unfavorable: it being found that of 8,000 Frenchmen marrying before 20

the death-rate is 50 per 1,000, while that of the unmarried is less than 7. In *women* the death-rate from 30 to 35 is 11 for spinsters, 9 for wives; from 50 to 55, the rates are 26 or 27 and 15 or 16. The mortality of spinsters from 15 to 20 in France is 7·53, of wives 11·86: from 20 to 25, 8·22 and 9·92.

869. In **military** sanitary statistics the ratios of sickness, invaliding and discharge for ill-health, and mortality to mean strength are the points chiefly requiring notice. They are generally calculated for annual periods, and per 1,000.

870. The **mean annual strength** is the sum of the numbers of men (or women or children) present at all the musters held within the year, divided by the number of musters. It must be remembered that this is the basis for estimating the sanitary condition of a body of troops, and can only be used to found an opinion upon the salubrity of a station when the latter has been occupied by the corps during the entire year. The total deaths during nine months' occupation of a post, for example, are not to be divided by the mean annual strength, to find the death-rate, but by three-fourths of that number or by the mean strength for the nine months.

871. The ratio per mille of **admissions to strength** is to be recorded; with subordinate ratios showing the proportionate shares of the principal tropical diseases, in percentage relation both to mean strength and to the total number of admissions. As a man may be admitted several times during the year and each admission counts in the total this ratio may exceed equality; that is the admissions may be more than 1,000 per 1,000. It is evident that this ratio is a very imperfect test of sanitary condition or of the loss of effective service caused by disease; since it may be raised by a large number of trifling and brief ailments much more than by a small number of serious and debilitating affections.

872. The true test of loss of efficiency due to unhealthiness is the **average daily** sick per mille, 365,000 times the mean strength divided by the sum of the numbers in hospital for each day.

873. Invaliding to **Europe** and **discharge** from service on account of ill-health must be kept in sight in interpret-

ing military statistics, because they are apt to fluctuate considerably through accidental circumstances and they affect inversely the ratios both of sickness and of mortality. The latter affords, on this account, an untrustworthy indication of the health of a body of soldiers.

874. **Mortality** statistics should include not only the general death-rate per 1,000 of mean strength but also the ratios which the principal causes of death, especially epidemic and preventible diseases, bear to the total and to each other.

875. To all these statistics should be added the numerical relations of **age** and length of **service** to disease, invaliding, discharge and mortality. Such ratios should express (for instance), not the number of deaths at a certain age per mille of mean strength, but per mille of all persons of that age; so that the ages of the living as well as of the diseased must be known and taken into consideration.

876. The statistics of **prisoners** need differ little from those of soldiers. Transfers and discharges on sanitary grounds are too rare to exercise any appreciable effect upon mortality statistics so as to prevent their affording a fair test of sanitary condition. There are some inquiries connected with jail-management in which the *aggregate* strength, that is, the sum of individuals constituting the jail population during the year, is preferable to the mean annual strength; as for instance in estimating the effect of punishment on health. This is a subject which, under the present system of jail superintendence, requires to be closely watched and its statistics carefully studied. The periods of confinement to which convicts are sentenced and nearness to time of release exercise influence on their health and should therefore be noted.

APPENDICES.

APPENDIX I.

FAMINE.

The Fourteenth Annual Report of the Sanitary Commissioner for Madras, 1877, contains an Appendix "On the Sanitary and Medical Aspects of Famine" by Surgeon-Major W. R. Cornish, F.R.C.S., of such value to Indian hygienists that it has been suggested that an abstract of its contents would be a useful addition to this manual Accordingly an attempt has been made in the following pages to give a *précis* of the results of the Sanitary Commissioner's observations for the benefit of students who have not access to the *Report* itself. The Appendix contains another paper of unique value by Surgeon-Major A. Porter, M.D., "Pathology in Famine Diseases," in which the morbid appearances observed in 450 autopsies are described.

The voluminous literature of Indian famines is remarkably deficient in information upon the effects of scarcity of food upon sickness and mortality. The importance, therefore, of putting into a form convenient for record and reference the facts which were observed during 1877, in the Madras Presidency, by the Sanitary staff, is obvious. Ordinary European officials are singularly ignorant of even the normal habits, as to food, of the people of this country, as of almost everything relating to their domestic life.* This ignorance, with the result of loose observation, has been productive of much disaster in famine administration. "Men whose practical experience guides them aright in apportioning the food of a horse in relation to his work go altogether astray when they have to deal with the question of the food of a human being in relation to labor

---

* For example: "An officer of the Civil Service, high in rank, who speaks the languages of the country with the fluency of a native, and who has lived a quarter of a century amongst the people, was under the impression that an Indian cooly habitually took only one meal in the twenty-four hours."

or to recovery from privation, simply because they are content to accept inaccurate data, basing their experience on defective evidence." Even the significance of the word "starvation" has been imperfectly apprehended by Famine officials. Sir R. Temple, for instance, telegraphing to the Government of India, on the 7th February 1877, "Over the whole of the Madras Presidency famine is successfully combated and *starvation prevented*"! The common belief has been that death by starvation is impossible so long as food can be obtained and swallowed. The truth has not hitherto been recognized by unprofessional observers that "a chronic insufficiency of food induces such a wasting of the tissues of the body that no subsequent attention to the nourishment of the victims of slow starvation can remedy the mischief occasioned by previous ill-feeding." The acute and chronic forms of starvation must be carefully distinguished. With the former famine administration has practically no concern. Much improvement in the methods of dealing with famines cannot be expected until the true meaning of starvation has been impressed upon the minds of those who have to deal with it. Sanitary officers are bound to do all in their power to disseminate the truth that chronic insufficiency of food is more fatal in its effects than pestilence.

As a preliminary to the consideration of the effects of dearth of food, the second chapter discusses food, labor and wages in non-famine times. The first popular fallacies to be exploded are the notions that the inhabitants of India live mainly upon grain, and that grain rice. In Southern India and the Deccan rice is not the staple food of the working population, five-sixths of whom live on millets. In Northern India the deficiency of cereals in nitrogen is compensated by the consumption of pulses. In the south, also, this class of food is used, but animal food is preferred when it can be had. "Milk, ghee and curds constitute an important part of the dietary of all classes of the people, but the agricultural poor have no scruples about eating flesh-meat, fish (fresh or salted), game, field-rats, snails, and any other animal matter that is capable of conversion into wholesome food. During the early period of famine cattle that died, or were killed to save them from dying of starvation, were the main support of many thousands of the people; and in the

famine-camps animal food was eagerly sought. The simplicity of Indian dietaries has been much exaggerated. Even Brahmans, whose work is sedentary, do not fare so simply as is supposed : and no class is exclusively vegetarian in its diet. All Indians use milk, curds and butter : and it is believed that, throughout the country, the laboring poor will eat, when they can get it, the fish and the flesh of sheep, goats and poultry. The Wudders of this Presidency, the hardest workers we have, eat meat, (chiefly pork), almost daily.

Careful enquiry has ascertained that a laboring man in good health consumes not less than 24 ounces of millet daily or somewhat more of rice :-and that twice this quantity is not too much in many cases. In Bengal, (according to Sir R. Temple,) the ordinary daily food of an adult laborer is 2 lbs. of rice, with about half a pound of fish, some pulse and condiments. In the South 2 lbs. of rice daily is considered about enough, and not too much, for a rice-eating laborer. Jail experience has shown that about 24 oz. of millet, with pulse or animal nitrogenous food, oil, salt, condiments, and green vegetables, will preserve in health and vigor a male adult undergoing ordinary "hard labor."

The agricultural laborer in Southern India is, for the most part, paid not in money but in food-grain ; and there is abundant evidence that he is, in ordinary times, so far as food is concerned, "just as well off as the agricultural laborer in Devonshire or Dorsetshire." Sir R. Temple's assumption that "the laboring poor can hardly get more than one pound a day for a male adult in ordinary times" is demonstrably false.

The laborer receiving, besides subsistence-wages in grain, five per cent. of the produce of harvest, his prosperity is closely connected with its abundance. When seasons are normal he has enough of food for himself and his family : but when harvests are scanty, or fail altogether, he cannot subsist and support his household without aid. This he generally fails not to obtain from his employer or master ; but a succession of bad seasons exhausts this source of supply, embarrassing farmers and approximating their condition to that of the laborers. Thus it had been before 1877. The rainfall

was excessive in 1874, scanty in 1875; in 1876 both monsoons failed over a wide extent of country. In the end of the latter year prices of food-grains had risen 300 per cent. above the average.

It appears, therefore, that, even in the most favorable years, certain large classes of the population, those especially who have no regular employment, "have very little margin of expenditure." A succession of bad years brings them low. The non-working sections of these classes—the old and the children—are the first to suffer when prices of food rise. In the present instance the want of sufficient food affected first the aged and the young of the laboring classes who had no settled occupations; next the agricultural laborers, who lost their share of produce; then the small farmers, the weavers and the village artizans, dependent upon agricultural prosperity for their own. Before the end of 1876 famine was sore in 8 of the 20 districts of this Presidency: and "probably one-fourth of the population of those districts had then begun resorting to unusual articles of food to help them in eking out their scanty and decreasing supplies of food-grains."

The Third Chapter treats of the Physical Signs of Chronic Starvation. The early indications are common enough in ordinary times: famine only intensifies ordinary phenomena. They are reducible to two heads;—ANÆMIA and UNDUE WASTE OF TISSUE.

Symptoms of deteriorated blood were generally very readily detected in the laborers on relief works and in applicants for assistance. At least 50 per cent. of the poor, while the famine was at its height, were anæmic. Great pallor of the mucous membranes (except of the conjunctiva of those who worked in the open air) is one of the earliest signs of insufficiency of food: the lips are pale, the tongue white and creamy. The circulation is feeble and irregular. In women and children there is "a peculiarly sad and 'drawn' expression of face, betokening anguish, the curved lines in the skin, running from the side of the nose to below the angle of the mouth, being very distinct and prominent."

Wasting soon follows upon insufficiency of food. The first evidence is the disappearance of sub-cutaneous fat

and of normal roundnesses. The skin appears thinner, and loosely attached. Later, the deeper deposits of fat disappear, especially in the gluteal, inguinal and pubic regions; in young women the fatty tissue of the mammary glands is absent. In March 1877 leanness was general; but in many cases muscular development had not yet suffered. The meat-eating classes maintained their vigor for some time longer, in consequence of the abundance and cheapness of the flesh of cattle which had died or been slaughtered when useless for labor. When this source of supply had been exhausted, these classes fell off rapidly. In Bellary, for instance, in April, about 30 per cent. of the laborers on relief-works were emaciated; in July scarcely one man or woman was capable of efficient work.

After an indefinite interval, the wasting advances from the fatty and cellular tissues to the muscles and other structures. "An unequivocal and almost universal sign of chronic starvation was *flattening of the nates.*" Every bony process of the frame became prominent, "and, with the gradual waste of body tissue, the strength and energy, and desire for life, disappeared. The brain and nervous tissue wasted simultaneously; and this fact probably accounts for that indifference which prevented so many from availing themselves of offered help."

How far such anæmia and wasting may proceed before a point is reached from which recovery is hopeless is most difficult to determine. While the external structures are wasting away internal organs are undergoing correspondent deterioration. The apparatus for absorbing albuminous nutriment from food becomes disorganized; and when the powers of digestion and assimilation have thus been seriously impaired, the danger to life is enormously increased. So gradual are the changes that the degree from which recovery is impossible may be reached insensibly. Hence the danger that in time of famine the assimilative functions may be irreparably weakened before the necessity for interference by public help has been recognized. "Any scheme of general assistance to the poor, to be of use, must be set afoot before these symptoms of impoverished blood and tissue-waste have become general; and whatever else a system of famine-relief may embrace, a due provision of daily food alone will enable the people to emerge from the disaster with vitality and energy unabated. * * *

In chronic starvation the victims die because the structural changes dependent on long continued wasting of tissues prevent the conversion of food into force and energy. * * * Experience in thousands of such cases in our relief hospitals shows how futile are efforts to deal with the effects of famine when the people have been permitted to waste away. Public money spent on comforts for the sick, while smoothing the path to the grave, was entirely wasted, so far as a restoration to health was concerned. The only economical application of State funds in famine times is the early help of the able-bodied poor to maintain their vigor, and the mode of accomplishing this end is a task demanding the exercise of the highest qualities of famine administrators."

As to the degree to which emaciation proceeds in chronic starvation, it has been established that the body gradually wastes from averages of 115 lbs., and 95 lbs., for men and women, to 77·1 lbs. and 61·4 lbs. When two-fifths of the normal weight of the body has disappeared life cannot be preserved: and death often takes place before this degree of wasting has been reached.

Other morbid conditions are noticed in detail. The first of these is a form of *scurvy* to which the poor are liable in times of drought and scarcity. Most of those affected with this complaint showed "a deep purplish blue discoloration and thickening of the gums, marked most distinctly in the upper jaw." Often there was ulceration, with bleeding and loosening of the teeth: but most commonly only a spongy thickening of the gum, sharply defined from the adjacent healthy structure. The scorbutic taint was most prevalent, in the driest districts, where vegetables were most scarce; it disappeared when rain fell and fresh vegetables were procurable. In some instances the scorbutic condition of the gums was observed in persons who had not yet lost flesh and who appeared in other respects healthy; but when the discolored band reached or exceeded a breadth of a quarter of an inch, muscular power had generally failed and the complication was regarded as unfavorable. When this condition exists without anæmia and emaciation it indicates defects in the quality of the food, especially to deficiency of the salts which vegetables supply: both quantity and quality are at fault when the three classes of symptoms concur.

In several relief-camps a peculiar morbid condition of the tongue and mucous membrane of the mouth was observed. The thick white fur, which coated the tongue in all bad cases, in some instances cracked and peeled off in strips, leaving a raw, glazed and tender surface exposed. The epithelium of the lips and inner surface of the mouth similarly peeled away; and the angles of the mouth were often excoriated. In young children the ulceration was aphthous in appearance. This condition is probably a stage of the scorbutic cachexia. In one jail many deaths were due to this ulcerative affection of the mouth and gullet.

The *skin* of the famine-stricken is characteristic. A scaly epithelium adheres to the skin proper, darker in color, often patchy, removable by scratching but not by washing, harsh and dry to touch. Returning smoothness of the skin is one of the earliest and most satisfactory indications of recovery from chronic starvation. Not so general as this altered condition of the skin, though common enough, was a change in the *hair*, apparently due to atrophy ot the pigment cells. The ends of the hairs became "red, auburn, yellow, or straw-color." The condition was most observable "in children and others who had been long exposed to privation without coming under relief." In young children the hair on the body was preternaturally long but destitute of pigment.

The apathy and languor of the famine-stricken indicate lesions of the *nervous system*: and Dr. Porter's autopsies showed that the brain wasted like other tissues, though to a less degree. The average weight of the brain of a well-fed Hindu male was found to be 41·8 oz., of a female 38·1 oz., and the ratio of brain-weight to body-weight 1 : 38·2 in males and 1 : 35·8 in females. The average weight of brain of 181 emaciated males was 41·4 oz., with a ratio to average body-weight of 1 : 30·5; and the average in 121 females was 37·2 oz., with a ratio of 1 : 26·3. These figures account for the dulness, apathy, inaptitude for labor and indisposition to the smallest exertion in their own behalf of the famine-stricken. These are an essential part of the symptoms of chronic starvation, and should be treated accordingly. "We might as well punish a raving lunatic for offences committed during a paroxysm of madness as deal harshly with the so-called 'obstinacy' of the starved poor. When these symptoms of impaired nerve function become

evident in a population, starvation has already had the victim in his grip, and we must be prepared to deal tenderly and humanely with the victims, just as we do with those whose bodily emaciation is evident to the eye."

Observations on *arrest of growth and development* were few. It was found that the weight of young boys and girls on relief-works steadily diminished, but growth in height was not noted. The arrival of puberty in girls was decidedly retarded.

The effects of famine on the *reproductive system* were well marked. Children born in the relief-camps were born half-starved. This fact, and the small proportion of pregnant women observable amongst the famine-stricken, suggested inquiries which, with the birth-statistics of the affected districts, led to the conclusion "that in famine times there is atrophy and wasting of the reproductive as of all other tissues, and that during a continuance of the food-distress the reproductive powers of a population are most seriously affected." The mammæ shrunk and ultimately disappeared; and even the gland itself was reduced to a rudimentary condition. There is little doubt that corresponding changes occurred in the ovaries, affecting permanently the capacity for child-bearing. Menstruation was scanty and irregular in the younger women and had prematurely ceased in the older. Pregnancy was rare. "In the Madras relief-camps with an average strength of more than 11,000 paupers * * and a constant succession of new arrivals, for a period of ten months, during which more than 100,000 passed through the camps, there were only 39 births." The birth-registration affords ample evidence of the effect of famine on fertility. "While during 1877 the death-registers in famine districts have been recording four, five or six times the ordinary mortality, the birth registration has been declining, going down to the lowest minima in the months * * which corresponded, as regards the duration of pregnancy, with the intensity of famine distress. * * * Even in districts where there was no actual famine, and to which the famine wanderers migrated, the dearness of food seemed to have caused a decrease in births. Taking the whole Presidency, the registered births were fewer by 25 per cent. in 1877 than the average of the two" previous "years: and in 1878, up to the present time, the birth-rate has continued

exceedingly low, scarcely one-half of the average, proving that the causes of infertility were of a general nature, affecting especially the classes of people who had suffered from privation. In my opinion a large number of women above the age of thirty, who in normal circumstances would have continued fruitful, have been permanently barren by the degenerative changes that have taken place in their ovaries and mammary glands." Lastly, the *secretion of milk* was most injuriously affected by privation. It was deficient in quantity, with a tendency to cease altogether: and, as regards quality, the analysis of a few samples of milk from relief-camps showed a deficiency of total solids, salts and casein.

Chapter IV treats of the General Diseases of Famine. The ordinary diseases of India, " cholera, small-pox and fevers are aggravated either by the depraved condition of health and lowering of vitality from bodily wasting, or by the circumstances of the food-dearth bringing the people under peculiar insanitary conditions."

During the years of excessive rainfall—1871-1874—*cholera* was absent. There is no evidence of a necessary connection between drought and cholera, but it has happened more than once before the present occasion that during a season of drought and scarcity of food the effects of cholera, if present, are intensified. It was so in 1833-34, in 1853-54 and in 1866. The use of unusual food tending to disorder the digestive organs; water for domestic purposes becoming scarce and foul; dirt, and crowding in relief camps—aggravate the intensity of cholera: and the wandering of the population favors its spread. In the present case cholera was most rife in the early period of scarcity, when the use of unaccustomed food and bad water, with crowding, began. The intensity of the disease had declined before the worst period of the famine had arrived; and the epidemic disappeared, over a large area, when rain fell and agricultural operations were resumed. There was undoubtedly a tendency to ascribe to cholera deaths which were really due to privation; but it is also certain that persons slowly dying of starvation were specially obnoxious to cholera attack, and that death was often hastened by a sudden onset of choleraic diarrhœa; some of the ordinary symptoms of cholera—cramps, vomiting and suppression of

urine—being frequently absent. The experience of 1877 shows "that if cholera is epidemic in a province during famine time, it must inevitably affect in an undue degree those who are famine-stricken, but that cholera is not a necessary or universal accompaniment of famine; and that the rise, progress and decline of cholera epidemics are in no way affected by the prevalence of famine."

Small-pox has prevailed in every period of famine. Dry weather is favorable to the disease; and during the continued drought of 1875, 1876 and 1877 a widely-spread epidemic raged in the famine districts and elsewhere: the mortality being higher in the former. Wandering and crowding contributed to diffuse the disease, helped by the indifference of the people to exposure to the infection. The registered mortality in 1877, due to this cause, was 88,321, the average of eleven previous years being 29,301. Vaccination was actively carried on and the annual number of operations was more than doubled. "If vaccination was compulsory in India, the administration in famine times would have one difficulty the less to contend with. Experience shows us that small-pox will always be a complication of famine, and the complication is so much the more embarrassing from the habitual neglect of vaccination under the voluntary system."

The lowering of the ground-water and overheating of the soil, which are the consequences of drought, are not favorable to the generation of malaria; paludal *fevers*, therefore, were rare so long as the drought continued. In May 1877 scarcely a case of fever of any kind could be found in the relief-camps. When, however, heavy rain fell and the soil became saturated, malarious fevers, intermittent or remittent, became very prevalent, and destroyed thousands of the half-starved survivors of the famine. After eight or ten days of fever dysentery or dropsy set in; in cold weather pulmonary affections often supervened. In the last two months of the year the mortality from fever was very high; and on the whole more deaths were due to this cause than to cholera or small-pox. It is obvious that a large proportion of the mortality thus classed under the heads of certain specified diseases was really the result of privation. This is demonstrated by the returns of deaths, which show that the mortality assigned to these diseases is two, three and four times as

great in a famine area as in neighbouring districts. It is impossible to separate the effects of specific disease from those of famine. In 1877 the registered death-rate, in Madras, in the famine area was three times as great as in the region free from distress. Cholera, small-pox and fevers prevailed in both areas; but even the mortality from these was enormously increased only in the famine tract.

In spite of repeated efforts, the value of the evidence afforded by the registry of births and deaths, imperfect as it confessedly is, was not appreciated: and a prediction that the population of the affected districts would be found to be diminished by one-fifth or one-sixth, when the dearth had passed away, was received with incredulity. A census of selected areas was ordered; and the result showed that the estimate founded upon the birth and death registers was too low. Instead of one-sixth to one-fifth it was found that from 20 to 25 per cent. of the population of the affected districts were missing when the famine ended. The total loss of population in the Madras Presidency may be fairly estimated at three millions.

Chapter V is devoted to the Special Diseases of Famine. Of these the commonest was a form of *diarrhœa* often complicated with *dysentery* and symptoms of ulceration of the lower bowel. It was a stage in the process of degeneration, coming after anæmia, emaciation and the scorbutic cachexia. As the disease advances the mucous membrane of the large intestine is partially destroyed, the evacuations containing mucus and blood. The food is imperfectly assimilated or not at all: wasting has progressed to an extreme degree, and there is proportionate weakness. The surface is cold, the pulse feeble, desire for food disappears, and death by asthenia closes the scene. The attitude of sufferers from this famine-disease is pathognomonic. "The limbs are flexed and brought close in contact with the trunk, and the patients will lie for hours and days in this posture, curled up in their blankets, taking food and medicines when given to them, but apparently very indifferent as to their fate. The end of such cases is sometimes complicated with acute dysentery—very frequently with general anasarca—and in certain seasons of the year with pneumonia."

In this affection the mucous membrane of the intestinal tract underwent a process of fatty degeneration, leading

to softening and then to atrophy, and destroying the apparatus provided for assimilating nutriment. The complex structures of the intestinal mucous membrane, once destroyed, are incapable of renewal; and at this stage neither diet nor medicine can restore health. Treatment was unavailing. Even in some cases in which the degenerative changes had not proceeded to an extreme degree and careful treatment had checked the diarrhœa, dropsy supervened and the patients died. During the worst period of the famine, before rainfall had generated malarious exhalations, it is probable that three-fourths of the famine mortality was due to diarrhœa and dysentery: the remainder being attributable to dropsy, debility and anæmia, or affections in which bowel-disease was not prominent. Later on fevers and lung-diseases complicated the bowel-affection.

Next to diarrhœa and dysentery *dropsy* was the commonest disease of the famine-stricken. It usually began at the feet and ankles, and face and eyelids. In some there was ascites, in others anasarca. It often was added to diarrhœa or came on when diarrhœa ceased. As famine progressed dropsies became more common. Malarial fevers were often followed by fatal dropsy. Ordinary treatment was unavailing. Inunction with cocoanut oil appeared beneficial in the treatment of the young, when the condition of the skin was sufficiently healthy to allow of absorption.

The nature of the food to which the starving were forced to have recourse and the insufficiency of salt in their sparing dietaries favored the increase of intestinal *worms*; and the ascaris lumbricoides was very prevalent. In the bodies examined by Dr. Porter these parasites were found in the stomach of 8 per cent. of males and 12·5 per cent. of females; in the small intestines of 45·4 and 50·5 per cent.

Unhealthy *ulcers* of the legs were very common, sometimes with phagedenic sloughing. In the jails the fetters often produced formidable ulceration. The cornea was not very commonly ulcerated. *Itch* abounded and was exceedingly unmanageable. *Vermin* on the head and body were unusually prevalent. *Guinea-worm* appeared to be more abundant, in the districts infested with it, during

the dry period of the famine, than in ordinary times. At least 50 per cent. of the coolies in famine-gangs in the Bellary and Cuddapah districts were affected with guinea-worm.*

* This Appendix gives a most imperfect idea of the value of Mr. Cornish's paper. It is very desirable that it, and Dr. Porter's which accompanies it, should be printed in a more accessible form.

APPENDIX II.

DIETARIFS.

The following DIETARIES are mostly those of the *Madras Medical Code;* the articles of food being reduced to their dietetic elements.* The signification of the letters heading the columns is as follows:

A, albuminates; in ounces.	D, salts; in grains.
B, carbo-hydrates; ,,	E, nitrogen; ,,
C, fat; ,,	F, carbon; ,,

The arrangement of the dietaries is alphabetical under the heads:—EMIGRANTS, LUNATICS, PRISONERS, SICK, and SOLDIERS (in health and freedom). It was laid down in Chapter IV that the quantities of each of the alimentary groups and of the nitrogen and carbon necessary for maintaining in health an adult man undergoing moderate labor were;—A 4·4 oz.; B 14 oz.; C 2·75 oz.; D 437 grs.; E 300 grs.; F 5,000 grs.

The following table has been employed in calculating the values of the constituents of the dietaries:—

Table for calculating Diets.

Articles.	In 100 ounces.					
	Albuminates (in ounces).	Carbo-hydrates (in ounces).	Fat (in ounces).	Salts (in grains).	Nitrogen (in grains).	Carbon (in grains).
Milk	4·0	5·0	3·0	262	276	2,844
Rice	6·3	77·7	0·7	215	435	17,075
Meat† (without bone).	15·0	...	8·4	700	1,035	6,398
Bread	8·1	50·8	1·67	565	559	12,300
Potatoes	1·5	22·0	0·2	437	103	4,806
Flour	10·8	68·6	2·0	740	745	16,800

* I am indebted to my friend Dr. Macrae for these reductions.
† Average meat contains 20 per cent. bone.

I.—Emigrants.

NATIVES.

24 ounces rice, 4 dholl, 1 ghee, ½ oil, 1 salt, ⅓ turmeric, 1 onions, 1 tobacco, ¼ chillies, 2 tamarind, 2 salt fish, ½ coriander, ¼ garlic, ¼ mustard, pepper, and cummin seeds.

—	A.	B.	C.	D.	E.	F.
Values	3·11	21·08	1·87	539	209	5.490

Remarks.—When the weather does not allow of cooking, 2 lbs. avil (or 1 lb. biscuit), 4 oz. gram, and 2 oz. sugar are served out daily to each adult.

II.—Lunatics.

EUROPEANS.

MILK.

32 ounces milk, 16 bread, ½ butter, ½ tea, 2¼ sugar.

Values .. .	2·58	11·87	1·66	172	177	3,450

SPOON.

8 ounces bread, ½ tea, 2¼ sugar.

Values	0·65	6·21	0·13	45	44	1,399

LOW.

8 ounces mutton (in broth),* 8 bread, 2 rice, ½ tea, 1½ sugar.

Values	1·98	7·04	0·82	105	135	2,113

HALF.

8 ounces mutton (in broth),* 16 bread, 2 rice, ½ butter, ½ tea, 1½ sugar.

Values	2·63	11·10	1·39	140	180	3,254

* Rice or barley and greens or onions and salt added to make the broth.

II.—Lunatics—(*Continued*).

Europeans—(Continued).

Full.

16 ounces meat (in broth),* 16 bread, 2 rice, 1 butter. $\frac{1}{2}$ tea, $1\frac{1}{2}$ sugar.

—	A.	B.	C.	D.	E.	F.
Values	3·83	11·10	2·53	206	262	3,924

III.—Prisoners.

1.—European Civil Prisoners (except at Ootacamund).

3 ounces meat,† (in soup), 22 bread, 19 potatoes, 7 flour, 1 dholl, $\frac{3}{4}$ suet, $1\frac{1}{7}$ coffee, 1 onions, 1 salt, $2\frac{1}{7}$ sugar, $\frac{1}{4}$ tea.

—	Mondays, Wednesdays, and Fridays.					
Values	3·49	22·81	1·44	710	241	5,771

4 ounces meat,† 14 bread, 16 potatoes, 7 flour, $\frac{3}{4}$ suet, $1\frac{1}{7}$ coffee, $2\frac{1}{7}$ sugar, $\frac{1}{4}$ tea, 1 salt, $\frac{1}{48}$ pepper.

—	Tuesdays, Thursdays, and Sundays.					
Values	2·73	17·46	1·37	645	187	4,539

3 ounces meat† (in soup), 22 bread, 11 potatoes, 8 rice, 7 flour, 1 dholl, 1 onions, $\frac{3}{4}$ suet, $1\frac{1}{7}$ coffee, $2\frac{1}{7}$ sugar, $\frac{1}{4}$ tea, 1 salt, $\frac{1}{48}$ pepper.

—	Saturdays.					
Values	3·87	27·23	1·48	692	266	6,753

* Rice or barley and greens or onions and salt added to make the broth.

† Without bone.

III.—Prisoners—(*Continued*).

1.—European Civil Prisoners (except at Ootacamund) —(*Continued*).

For Prisoners undergoing Simple or Solitary Confinement for 21 Days or under.

20 ounces bread, 40 milk, 5 flour, 1 suet, 1 onions, 1 salt.

—	A.	B.	C.	D.	E.	F.
Values	3·76	15·59	2·46	671	259	4,731

2.—European Military Prisoners.

16 ounces bread, 8 meat,* 2 milk, 10 vegetables, 4 sugar, ½ tea, ½ salt.

—	Sundays, Tuesdays, and Fridays.					
Values	2·70	13·23	0·99	389	184	3,537

16 ounces bread, 9 pease, 12 milk, 4 sugar, ½ tea, ½ salt.

—	Mondays and Thursdays.					
Values	3·85	17·87	0·79	426	265	4,565

16 ounces bread, 24 potatoes, 12 milk, 4 sugar, ½ tea, ½ salt.

—	Wednesdays and Saturdays.					
Values	2·14	17·81	0·66	433	147	4,200

* Without bone.

III.—Prisoners—(*Continued*).

3.—Natives in Madras Jails.

The following four dietaries are now (November 1879) in use in district and subsidiary jails experimentally; and, if they are found suitable, that for Class IV will probably be introduced into the central jails.

Class I.—Convicts sentenced to Seven Days and under.

20 ounces dry-grain, ½ ounce salt.

—	A.	B.	C.	D.	E.	F.
Values	2·00	13·85	0·91	442	140	3,529

Class II.—Convicts sentenced to more than Seven Days and not more than One Month.

20 ounces dry-grain, 2 dholl, ½ ghee or oil, ½ salt, ½ curry powder.

Values	2·44	15·09	1·45	469	170	4,038

*Class III.—Prisoners under trial and Convicts sentenced to more than One Month and not more than Four Months.**

20 ounces dry-grain, 2 dholl,* 10 tyre,† ½ ghee or oil, ½ tamarind, ¾ salt, ½ curry-powder, 4 vegetables, ½ onions.

Values	2·89	16·09	1·63	611	201	4,399

Class IV.—Male Convicts sentenced to Rigorous Imprisonment for more than Four Months.‡

24 ounces dry-grain, 2 dholl, 10 tyre,§ ½ ghee or oil, ½ tamarind, ¾ salt, ½ curry-powder, 4 vegetables, ½ onions, 5 mutton‖ or fish, 30 grains garlic.

Values	3·64	18·34	2·05	667	253	5,168

* 3 oz. after the first month. † Only three times a week.

‡ Non-laboring males, females, and juveniles to get one-fifth less of grain and mutton.

§ Tyre thrice a week.

‖ Without bone; on the four days on which tyre is not given.

III.—Prisoners—(*Continued*).

4.—Natives in Bombay Presidency.

Long-term Adult Males on Extramural Labor.

20 ounces flour (wheat or dry-grain), 5 dholl, 1 oil, ½ tamarind, ⅜ salt, ½ curry-stuff, 8 vegetables.

——	A.	B.	C.	D.	E.	F.
Values	3·36	17·78	1·50	395	230	4,756

Long-term Adult Males on Intramural and Medium Labor.

20 ounces flour (wheat or dry-grain), 4 dholl, ¼ oil, ⅜ salt, ¼ curry-stuff, 6 vegetables.

Values	3·11	16·92	0·73	376	213	4,277

Adult Males sentenced to Hard Labor for three months and under, or to Simple Imprisonment, or Under Trial; Women and Juveniles.

19 ounces flour (wheat or dry-grain), 3 dholl, ¼ oil, ⅜ salt, ¼ curry-stuff, 6 vegetables.

Values	2·78	15·41	0·69	354	190	3,940

5.—Natives in Bengal Province.

Bengalees, Ooriahs, and Assamese; convicted Non-laboring Prisoners; per week.

126 ounces rice, 30 dholl, 4⅔ oil, 3½ salt, 40 vegetables.

Values per day ...	2·15	17·31	0·88	321	147	4,168

Same; Laboring and Under-trial.

140 ounces rice, 28 dholl, 16 animal food, 4⅔ oil, 3½ salt, 3½ condiments, 40 vegetables.

Values per day ...	2·55	18·70	1·08	338	175	4,615

III.—Prisoners—(*Continued*).

Natives of Behar, North-West Provinces, and Punjab; Convicted Non-laboring Prisoners; per week.

70 ounces rice, 56 wheat flour, 34 dholl, $4\frac{2}{3}$ oil, $3\frac{1}{2}$ salt, $3\frac{1}{2}$ condiments, 36 vegetables.

—	A.	B.	C.	D.	E.	F.
Values per day ...	2·63	16·89	0·99	370	180	4,234

Same; Laboring and Under-trial; per week.

84 ounces rice, 70 wheat flour, 26 dholl, 16 animal food, $4\frac{2}{3}$ oil, $3\frac{1}{2}$ salt, $3\frac{1}{2}$ condiments, 28 vegetables.

Values per day ...	3·05	18·97	1·23	386	209	5,057

6.—Natives in Punjab.

Laboring Adult Males; per week.

40 ounces wheat (second quality), 48 cholum, 72 cumboo, 24 dholl, 24 meat, 66 tyre, 24 vegetables, $3\frac{1}{2}$ salt, $3\frac{1}{2}$ condiments, $1\frac{1}{2}$ ghee.

Values per day ...	3·93	19·37	1·59	523	271	5,187

Non-laboring Adults, Women, and Boys under 15; per week.

32 ounces wheat (second quality), 40 cholum, 60 cumboo, 16 dholl, 18 meat, 48 tyre, 24 vegetables, $3\frac{1}{2}$ salt, $3\frac{1}{2}$ condiments, $1\frac{1}{2}$ ghee.

Values per day ..	3·06	15·67	1·31	459	210	4,178

IV.—Sick.

1.—General Hospital, Madras.

Spoon.

2 ounces sago, ½ tea, 2¼ sugar, 6 milk.

—	A.	B.	C.	D.	E.	F.
Values	0·26	4·07	0·18	15	17	906

Tea.

¾ ounce tea, 8 bread, 3 sugar, 9 milk, 4 arrowroot.

Values	1·01	10·65	0·40	68	70	2,425

Beef-tea.

6 ounces beef* (for beef-tea), ½ tea, 16 bread, 1½ sugar, 6 milk.

Values	2·44	9·85	0·93	147	167	2,799

Milk.

40 ounces milk, 12 bread, ½ tea, 1½ sugar, 2 rice, ½ butter.

Values	2·70	11·07	1·85	177	186	3,389

Chicken.

8 ounces chicken, 12 bread, ½ tea, 1 butter, custard pudding.

Values	2·73	7·73	2·16	176	258	2,970

* Partly lost as food.

IV.—Sick—(*Continued*).

1.—General Hospital, Madras—(*Continued*).

Low with Pudding.

8 ounces mutton (in broth), 12 bread, ½ tea, ½ butter, rice pudding.

——	A.	B.	C.	D.	E.	F.
Values	3·19	8·88	1·94	181	220	3,083

Low.

8 ounces mutton (in broth), 16 bread, ½ tea, 1 butter.

Values	2·50	8·13	1·84	146	171	2,794

Half.

10 ounces meat, 16 bread, 8 potatoes, ½ tea, 1 butter.

Values	2·92	9·89	2·02	195	199	3,306

Fish.

8 ounces fish, 16 bread, 8 potatoes, ½ tea, 2 butter.

Values	2·86	9·89	2·32	161	196	3,400

Mixed.

8 ounces mutton, 8 rice, 4 vegetables, 8 bread, ¼ coffee, 1 butter, 6 hoppers.

Values	2·78	15·35	1·82	143	188	4,304

Full.

12 ounces meat, 16 bread, 12 potatoes, ½ tea, 1 butter.

Values	3·28	10·77	2·10	226	225	3,626

IV.—Sick—(*Continued*).

2.—European Soldiers in Hospital.

Spoon.

2 ounces sago, ½ tea, 2¼ sugar, 6 milk, 2 rice, ⅛ salt.

—	A.	B.	C.	D.	E.	F.
Values	0·39	5·62	0·19	71	26	1,247

Tea.

8 ounces bread, ¾ tea, 3 sugar, 9 milk, 2 rice, ⅛ salt, 4 arrowroot.

Values	1·14	12·20	0·41	124	78	2,766

Beef-Tea.

16 ounces bread, ½ tea, 1½ sugar, 6 milk, 12 beef,* ⅜ salt.

Values	3·34	9·85	1·44	381	230	3,183

Low Milk.

3 ounces arrowroot, 36 milk, 3 sugar, ½ tea, 8 chicken, 4 bread, ⅜ salt.

Values	3·44	9·14	1·44	210	237	3,037

Milk.

12 ounces bread, 3 rice, 46 milk, ½ butter, 2¼ sugar, ½ tea, ⅛ salt.

Values	3·01	12·84	2·04	246	205	3,868

* Most of this is lost as food.

IV.—Sick—(*Continued*).

2.—European Soldiers in Hospital—(*Continued*).

Chicken.

8 ounces fowl, 12 bread, ½ tea, 2½ sugar, 26 milk, 1 butter, ⅜ salt, ½ barley, 1 onions, ½ flour, 2 eggs.

——	A.	B.	C.	D.	E.	F.
Values	4·12	10·46	2·46	357	283	3,835

Low with Pudding.

8 ounces mutton* (in broth), 12 bread, ½ tea, 2¼ sugar, 21 milk, ½ butter, 1 onions, ½ barley, ½ flour, ⅜ salt, 2 rice, 2 eggs.

Values	3·57	11·53	2·24	363	245	3,853

Low.

8 ounces mutton,* 16 bread, ½ tea, 1½ sugar, 6 milk, 1 butter, 1 onions, ½ barley, ½ flour, ⅜ salt.

Values	2·83	10·54	2·04	325	194	3,405

Half.

10 ounces mutton,* 16 bread, 8 potatoes, ½ tea, 1½ sugar, 6 milk, 1 butter, 1 onions, ½ barley, ½ flour, ⅜ salt.

Values	3·25	12·30	2·22	374	222	3,917

* Without bone.

IV.—Sick—(*Continued*).

2.—European Soldiers in Hospital—(*Continued*).

FISH.

8 ounces fish, 16 bread, 8 potatoes, ½ tea, 1½ sugar, 6 milk, 2 butter, ⅜ salt.

——	A.	B.	C.	D.	E.	F.
Values	3·10	11·61	2·50	332	212	3,846

FULL.

12 ounces beef* or mutton,* 16 bread, 12 potatoes, ½ tea, 1½ sugar, 6 milk, 1 butter, 1 onions, ½ barley, ½ flour, ¾ salt.

Values	3·61	13·18	2·61	405	361	4,237

3.—Native Soldiers in Hospital (on Foreign Service).

SPOON.

4 ounces sago, 2 sugar, 6 milk, 2 rice, ⅛ salt.

Values	0·41	7·01	0·19	71	28	1,522

MILK.

12 ounces bread or rice, 40 milk, 2 sugar, 2 rice, ⅛ salt.

Values	2·59	13·15	1·34	207	178	3,610

LOW.

6 ounces mutton* or fowl in broth, 12 bread, 1 butter, 1 onions, ½ barley, ½ flour, 1 salt.

Values	1·78	6·79	1·52	526	124	2,261

* Without bone.

IV.—Sick—(*Continued*).

3.—Native Soldiers in Hospital (on Foreign Service)—(*Continued*).

Full.

6 ounces mutton* or fowl in curry, 8 rice, ½ curry-powder, 4 country vegetables, 8 bread, 1 butter, 1 salt, 6 hoppers.

—	A.	B.	C.	D.	E.	F.
Values	2·30	15·35	1·54	537	157	4,099

V.—Soldiers.

1.—European Soldiers' Ration.

16 ounces bread, 16 meat,† 4 rice, 2½ sugar, ⅝ tea, 1 salt, 16 vegetables.

Values	3·67	15·53	1·35	652	252	4,352

2.—European Soldiers on Shipboard.

Troops or Third-class Male Passengers; per Week.

24 ounces salt beef,† 12 flour, 2 suet, 4 raisins, 24 salt pork, ⅞ split pease, 36 preserved meat, 4 compressed vegetables, 36 biscuit, 64 fresh bread, 4 rice, 112 malt liquor, 4 preserved potatoes, 18 sugar, 3½ tea, 2⅔ vinegar, ½ mustard, 6 pickles, ⅙ pepper, 2 salt.

Values per day ...	3·35	14·58	2·79	342	230	4,581

3.—Native Soldiers on Foreign Service—Ration.

32 ounces rice, 3 dholl, 2 ghee, ¾ salt, ⅛ turmeric, 1¼ tobacco.

Values	2·66	26·66	2·30	419	181	6,660

* Without bone. † With bone.

APPENDIX III.

MADRAS RAINFALL.

The upper lines of figures give the mean rainfall in the Districts of the Madras Presidency for the period 1870–74; the lower figures for 1875–78.

Districts.	No. of Gauge Stations.	January.		February.		March.		April.		May.		June.	
		Rain.	Days.	Rain.	Days.	Rain.	Days.	Rain.	Days.	Rain.	Days.	Rain.	Days.
Bellary ...	16	0·08	...	0·01	...	0·06	...	0·62	2	2·86	5	2·80	6
		0·00	...	0·00	...	0·31	1	0·42	1	1·66	4	3·36	6
Chingleput ...	7	1·05	1	2·11	1	0·32	...	0·49	...	3·22	2	2·72	5
		0·19	1	0·05	...	0·16	...	0·31	...	3·46	3	2·09	5
Coimbatore ...	10	0·26	...	0·67	1	0·49	1	1·89	3	2·77	5	2·14	5
		0·05	...	0·02	...	0·42	1	1·70	3	3·59	6	1·62	4
Cuddapah ...	11	0·42	...	0·22	...	0·22	...	0·25	...	3·05	...	2·48	3
		0·00	...	0·00	...	0·63	1	0·32	1	1·73	3	2·19	4
Ganjam ...	16	0·44	1	0·13	...	0·68	1	1·26	3	1·82	3	6·77	8
		0·38	1	0·85	2	1·76	2	1·06	2	3·79	5	2·93	6

Districts.	No. of Gauge Stations.	July.		August.		September.		October.		November.		December.	
Bellary ...	16	2·68	7	3·41	7	6·22	10	6·89	9	0·86	2	0·25	1
		2·77	7	3·47	7	4·80	9	4·75	7	0·74	1	0·20	...
Chingleput ...	7	4·22	9	4·99	9	7·04	8	10·60	10	13·32	12	2·99	4
		2·84	6	4·99	10	5·30	7	4·52	7	5·72	6	1·45	3
Coimbatore ...	10	1·78	5	2·36	4	2·95	6	4·44	9	4·37	7	0·61	2
		1·44	5	2·19	5	3·27	7	6·27	10	2·31	6	2·97	3
Cuddapah ...	11	3·39	5	4·11	7	7·07	6	9·42	9	3·27	9	0·76	5
		3·05	6	4·53	9	5·62	9	3·86	7	1·10	3	0·41	1
Ganjam ...	16	6·55	11	7·07	13	7·26	12	10·12	9	1·79	2	0·65	1
		5·07	10	7·55	12	9·88	12	7·92	8	1·60	2	3·18	1

Districts.	No. of Gauge Stations.	January. Rain.	January. Days.	February. Rain.	February. Days.	March. Rain.	March. Days.	April. Rain.	April. Days.	May. Rain.	May. Days.	June. Rain.	June. Days.
Gódávari ...	20	0·32	...	0·20	...	0·42	...	0·44	1	1·82	3	4·53	6
		0·26	1	0·37	1	0·30	1	0·39	1	2·88	4	2·90	5
Kistna ...	11	0·87	...	0·06	...	0·30	...	0·24	...	1·51	3	3·16	6
		0·33	1	0·12	...	0·83	1	0·35	1	2·34	3	2·72	6
Kurnool ...	9	0·16	...	0·00	...	0·03	...	0·32	...	2·01	4	3·46	7
		0·00	...	0·00	...	0·48	1	0·48	1	1·50	2	2·29	5
Madras ...	1	1·40	2	1·32	2	0·58	1	0·61	1	2·49	2	3·63	11
		0·06	1	0·00	...	0·30	1	0·45	1	6·03	5	1·61	8
Madura ...	13	0·87	2	1·22	3	0·47	1	1·67	3	1·80	3	1·19	2
		0·36	1	0·03	...	0·70	1	2·35	3	2·38	4	1·17	3

Districts.	No. of Gauge Stations.	July. Rain.	July. Days.	August. Rain.	August. Days.	September. Rain.	September. Days.	October. Rain.	October. Days.	November. Rain.	November. Days.	December. Rain.	December. Days.
Gódávari ...	20	6·36	11	4·69	7	8·39	11	10·84	11	1·75	2	0·45	1
		6·80	10	7·45	11	7·38	10	7·21	8	1·17	1	0·83	1
Kistna ...	11	4·82	10	4·32	9	6·67	11	8·35	10	1·89	3	0·31	1
		5·88	10	6·78	12	5·72	9	7·26	8	1·01	2	0·10	1
Kurnool ...	9	5·11	10	4·23	8	8·87	10	5·20	9	0·89	2	0·40	1
		4·27	8	5·34	9	5·67	9	4·45	7	0·59	1	0·03	...
Madras ...	1	5·14	15	4·40	14	6·37	13	15·92	16	17·33	17	4·62	7
		2·89	12	4·54	16	4·27	11	5·58	12	9·96	12	2·69	8
Madura ...	13	0·82	2	2·62	5	1·87	4	4·34	8	5·36	9	1·65	3
		1·23	3	2·16	4	2·74	5	6·85	9	5·97	9	4·44	5

Districts.	No. of Gauge Stations.	January.		February.		March.		April.		May.		June.	
		Rain.	Days.	Rain.	Days.	Rain.	Days.	Rain.	Days.	Rain.	Days.	Rain.	Days.
Malabar ...	15	0·73	1	0·45	1	0·61	1	3·56	6	9·66	11	34·38	25
		0·01	...	0·04	...	0·96	2	2·71	5	4·68	8	32·72	25
Nellore ...	17	0·84	1	0·68	...	0·14	...	0·12	...	1·53	2	1·55	3
		0·19	1	0·10	...	0·54	1	0·23	1	2·50	3	1·39	3
North Arcot ...	17	0·44	...	1·23	...	0·61	...	0·34	1	4·90	3	2·62	5
		0·08	...	0·08	...	0·24	...	0·44	1	2·68	5	2·80	5
Salem	10	0·13	...	0·49	1	0·62	1	1·05	2	5·45	5	2·28	5
		0·03	...	0·00	...	0·78	1	1·47	2	3·99	7	2·91	4
South Arcot ...	8	0·26	...	1·63	1	0·22	...	1·01	...	3·44	3	1·98	4
		0·18	...	0·10	...	0·04	...	0·73	1	3·38	4	1·77	3
		July.		**August.**		**September.**		**October.**		**November.**		**December.**	
Malabar ...	15	33·20	24	11·84	19	9·37	16	8·57	13	3·53	6	0·86	2
		25·16	25	20·50	23	12·44	17	10·18	14	2·87	6	1·04	3
Nellore ...	17	3·16	6	3·26	5	4·78	7	11·65	9	8·82	7	2·04	2
		2·38	5	3·75	7	4·20	7	6·16	7	2·65	4	2·33	3
North Arcot ...	17	3·71	7	4·45	8	8·33	9	8·69	10	6·71	8	1·36	3
		2·99	6	6·44	10	5·89	9	4·79	7	2·91	5	1·07	3
Salem	10	2·96	6	4·92	8	7·24	10	7·33	9	3·14	6	1·22	13
		2·72	5	3·98	7	6·05	9	6·39	9	2·74	4	0·70	1
South Arcot ...	8	3·34	6	5·50	8	6·51	9	8·97	10	10·67	11	3·39	4
		2·27	5	6·07	10	6·58	9	4·78	7	6·31	8	2·76	5

Districts.	No. of Gauge Stations.	January. Rain.	January. Days.	February. Rain.	February. Days.	March. Rain.	March. Days.	April. Rain.	April. Days.	May. Rain.	May. Days.	June. Rain.	June. Days.
South Canara ...	5	0·99	...	0·21	...	0·16	...	1·19	2	9·77	5	39·50	26
		0·00	...	0·00	...	0·27	1	1·27	3	2·65	6	38·11	25
Tanjore ...	10	1·23	2	1·79	2	0·21	...	1·99	2	2·92	2	2·05	3
		0·92	1	0·01	..	0·14	...	0·55	1	2·51	4	1·17	3
Tinnevelly ...	11	2·49	3	1·81	3	1·20	2	1·55	3	1·39	3	0·79	2
		0·51	1	0·08	1	1·13	2	2·37	4	1·38	3	1·98	2
Trichinopoly ...	5	0·67	1	1·14	2	0·07	...	1·39	2	2·93	4	2·15	3
		0·44	1	0·00	...	0·26	1	1·37	2	3·70	6	1·06	2
Vizagapatam ...	15	0·53	1	0·33	..	0·31	...	0·92	1	2·04	3	5·14	7
		0·34	1	0·51	1	0·83	1	0·73	1	4·21	5	2·78	4

Districts.	No. of Gauge Stations.	July. Rain.	July. Days.	August. Rain.	August. Days.	September. Rain.	September. Days.	October. Rain.	October. Days.	November. Rain.	November. Days.	December. Rain.	December. Days.
South Canara ...	5	49·05	30	21·47	24	15·31	21	9·54	14	1·79	4	0·28	1
		36·11	28	32·00	29	17·32	27	6·75	11	1·16	3	0·66	1
Tanjore ...	10	2·75	5	4·61	9	4·46	9	8·63	11	10·62	13	5·16	9
		1·32	3	4·57	8	4·37	7	5·68	8	8·55	11	6·01	6
Tinnevelly ...	11	0·32	1	0·74	2	1·13	2	2·85	6	8·06	11	1·86	4
		0·51	2	0·72	2	1·32	3	5·55	9	6·01	10	5·08	6
Trichinopoly ...	5	2·09	3	4·55	6	4·35	6	8·59	12	7·07	10	2·33	4
		2·10	3	3·70	6	5·39	8	6·13	10	3·49	7	2·30	5
Vizagapatam ...	15	5·51	8	6·23	9	6·99	10	10·75	9	1·85	2	1·10	1
		5·07	9	6·14	10	8·40	12	9·29	8	1·15	2	4·63	1

APPENDIX IV.

MEDICAL INSPECTION AND QUARANTINE OF SHIPPING.

The following are the Rules referred to in para. 837.

MEDICAL INSPECTION.

1. The master of every vessel on board of which there is, either among the passengers or crew, any case of cholera, small-pox, or other epidemic disease common in India, shall report such case or cases to the pilot or other boarding officer at the earliest opportunity, or, in the absence of a pilot or other boarding officer, shall hoist a signal, which shall be during the day flag R of the Commercial Code, at the main, and during the night two lighted lanterns, one over the other, at the fore.

2. The Port Officer, having received information from the pilot or other boarding officer, or by signal, that any case of such disease is on board, shall communicate the information to the Health Officer of the port.

3. The Health Officer, as early as possible after receipt of this information, shall inspect the vessel, and more especially its sanitary condition; shall inquire into the circumstances attending the case or cases of the said disease; and shall arrange for the conveyance of all persons suffering from such disease to a hospital, unless the sick person or his friends can make adequate provision elsewhere.

4. The latter part of Rule No. III is, however, not to be enforced in the case of passengers bound for an onward port, unless under the clearest necessity; and of every such case a special report, explaining the reasons for the action taken, must be submitted to the Government.

5. Where the disease or diseases in question are limited to one or two cases, the vessel shall not be prohibited from

taking up the usual place of anchorage in the harbour, nor shall the passengers be detained on board pending the inspection of the Health Officer; but the master of the vessel shall be held responsible that no passenger suspected of having such disease is allowed to depart before this inspection.

6. Where cases have been more numerous than one or two, or when from their occurring on pilgrim or emigrant ships, or for other special reasons, further precautions may be deemed advisable, the vessel shall anchor in the place appointed for the purpose; and none of the passengers shall be allowed to leave until the Health Officer has made his inspection.

7. Vessels coming under this last rule shall be thoroughly cleansed and fumigated under the directions of the Health Officer. In the case of small-pox, it shall also be his duty to vaccinate, or have vaccinated, all those on board who appear to require this protection and are willing to accept it.

QUARANTINE.

1. The commander of every vessel, including buggalows on other native craft, arriving from a port where plague or yellow fever prevails, shall, before entering the harbour, indicate by signal the port from which she has come.

2. Such commander shall not, without having first obtained permission as hereinafter provided, allow any communication either with the pilot boat, except orally, or with the shore, or with any other vessel or boat in the harbour.

3. Immediately on the signal of such arrival being made, the Health Officer of the port shall go alongside the vessel, and ascertain by inquiry from the commander whether any person on board is then suffering, or has during the voyage suffered, from plague; and if such officer is satisfied by such inquiry that no such case has occurred, he shall, by writing under his hand, to be delivered to the commander, permit free communication between such vessel and the shore, and with other vessels and boats in the harbour.

4. If the Health Officer shall have reason to believe that any such case has occurred, he shall direct the com-

mander to take the vessel to the quarantine anchorage duly appointed and notified by Government, there to remain for the space of fifteen days from the day of arrival in the harbour or from the date of the occurrence of the latest case of illness, and shall further direct the commander to prohibit, during the said fifteen days, all communication, except such as is hereinafter provided for, between such vessel and the shore, or other vessels or boats in the harbour. The Health Officer may further direct the removal of so many of the passengers and crew as may not be suffering from sickness, and whose services may not be required on board the ship, to such particular spots as may from time to time be fixed upon by the Local Government as places of quarantine, there to remain for a space of fifteen days, or, in the event of the occurrence of a case of sickness, for a space of fifteen days from the date of the occurrence of the last case.

5. Any mails or cargo which may be brought by any vessel so arriving, shall be landed under such precautions as may be deemed necessary by the Health Officer to prevent the spread of the disease.

6. It will be the duty of the Superintendent of Marine to facilitate the conveyance to the vessel in quarantine of all supplies of provisions, stores, and other articles required by those on board. These supplies should be placed on the boats of the vessel, to be subsequently removed by members of her crew.

APPENDIX V.

MADRAS STATISTICS.

THE Presidency of Madras includes an **area** of 139,698 square miles. It is divided into 21 districts,* besides the Native principality of Pudukóta, the latter contributing 1,380 square miles of the total area given above. The districts are divided into 156 *taluks*, subdivided into 55,421 villages.

The total **population**, according to the census of 1871, was 31,597,872. The average population of each taluk was 200,520; of each village 564·4, varying from 251·6 in Vizagapatam to 5,234·4 in Malabar; of each house about 5, varying from 3·55 in the Nilgiri and 3·98 in Cuddapah to 7·67 in South Arcot and 7·68 in Madras City. The average number of houses in a village varies from 57 in Vizagapatam to 1,008 in Malabar, the mean being 112·4. There are 226·2 persons to the square mile, varying from 66 in the Nilgiri and 117·7 in Vizagapatam to 540·1 in Tanjore and 14,724·1 in Madras City.

The **religions** of the population were as follows:—Hindus 28,863,978, Mahomedans 1,857,857, Christians 531,178 (490,299 Natives, 14,505 Europeans, 26,374 Eurasians), Jains 21,254, undistinguished 6,910.

Emigration to Ceylon, Mauritius, Bourbon and the West Indies proceeds annually to a considerable extent, and a large proportion of emigrants return to India. In 1871, 89,529 persons emigrated to Ceylon and 68,310 returned; the corresponding means for 10 years (1862–1871) are 70,667 and 54,052. The movement to and from

* Some detailed statistics of each district, and of territories garrisoned by the Madras Army but not included within the Madras Presidency, are given in the following pages; the arrangement of the divisions being alphabetical.

the other three places mentioned is comparatively unimportant. In 1871, 3,308 persons left Madras ports for Mauritius, Bourbon and the West Indies, and 1,293 returned; the corresponding means for the 10 years were 5,557 and 888.

The number of **dwellings** in the Presidency was 6,229,954; of which 371,960 (6 per cent.) were empty on the night of the census. Classified according to their construction, 492,279 were *terraced*, 447,420 were *tiled*, 5,180,146 were *thatched*, and the character of 110,109 was unspecified. 2,505,539 persons occupied terraced houses, (average 5); 2,693,827 occupied tiled houses, (average 6); 25,391,540 thatched houses, (average 4·9); and 125,826 were not inmates of houses on the census night, of whom 80,045 were in Malabar.

The proportions of the **sexes** cannot be accurately ascertained in this country, owing to peculiarities of Native feeling. In the entire Presidency 502 males and 498 females per 1,000 were enumerated and the proportion was 99 females to 100 males. In eight districts only did females appear to preponderate, in the ratio 103·6 : 100. In Bellary the ratio was 93·9 : 100, in Vizagapatam 94·5 : 100, in Ganjam 95·1 : 100, in Cuddapah 94·9 : 100. In Malabar, South Canara and South Arcot the percentages of females, as returned, were 99·2, 99·8, 98·2, respectively; in Tanjore 106·9, in Pudukóta 108·4. Hindus (including Native Christians and Buddhists) returned 99 : 100, Mahomedans 100·3 : 100, Eurasians 102 : 100, Europeans 46·2 : 100.

If the **ages** be grouped in decennial periods and compared, as in the following Tables,* with the corresponding numbers for England and Wales in 1861, it will be apparent that children below 10 are more abundant, proportionately, in India than in England, and persons above 50 less; while Madras possesses less than half of the English proportion of persons above 60.

* Taken, with most of the other information given in this Appendix, from Mr. Cornish's most valuable Report on the Madras Census of 1871. His Report for 1878, as Sanitary Commissioner, has supplied the other figures.

Ages.	10		20		30		40	
—	M.	F.	M.	F.	M.	F.	M.	F.
British Census, 1861 ...	25·0	24·4	20·6	19·6	16·3	17·5	12·8	13·2
Madras Census, 1871 ...	32·5	32·4	19·5	19·5	17·6	18·9	12·5	11·7

Ages.	50		60		Above 60		Unknown.	
—	M.	F.	M.	F.	M.	F.	M.	F.
British Census, 1861 ...	10·2	10·3	7·1	7·1	7·0	7·7	...	...
Madras Census, 1871 ...	8·2	7·9	5·1	5·1	3·1	3·3	1·6	1·2

The **birth-rate** cannot be even approximately ascertained, under the present unsatisfactory system of registration. Mr. Cornish is of opinion that not more than one-half of the actual births are registered. The number for 1873 was 538,123, 17·7 per 1,000, 106 males to 100 females. The average birth-rate yielded by the municipal towns (with a population of 1,561,771) is 26·5 per mille, but this also is below the truth. In some towns a rate of 50 per 1,000 is registered, and it is probable that less than 30 is uncommon.

The registration of **deaths** is almost equally unsatisfactory. The number registered in 1873 was 513,232, 109 males to 100 females; but it is doubtful if this amounts to more than two-thirds of the actual mortality. The death-rate given by the registers is 16·9 per 1,000 in the rural districts and 27·7 in the municipal towns. The average for the whole Presidency was nearly 17 per 1,000, which will be reduced to 16·5 if 10,760 still-births are deducted. In the following Table the ages of the population and the deaths according to ages are given as supplied by the present imperfect registration :—

Ages.	Population.	Deaths.	Per mille.
Under 6 ...	6,580,599	165,244	25·1
6 to 12 ...	4,812,372	28,532	5·9
12 to 20 ...	4,851,742	28,347	5·8
20 to 30 ...	5,702,078	46,800	8·2
30 to 40 ..	3,778,993	44,183	11·6
40 to 50 ...	2,527,838	43,498	17·2
50 to 60 ..	1,593,982	50,481	31·6
Above 60 ...	983,719	95,387	96 9
Unknown* ...	449,824	...	...

In the following Table the **infirmities** of the general population are given as returned in the census. Persons of unsound mind appear to number about 0·45 per 1,000. In the "deaf or dumb" return persons deaf by age are included. The blind are about 1·9 per 1,000, most of them being aged. Leprosy appears to be less common inland than on the coast, and the proportion in the several districts ranges from 0·2 to 1·0 per 1,000.

Infirm.	Males.	Females.	Total.
Insane	4,088	3,447	7,535
Idiotic	3,491	2,991	6,482
Deaf *or* Dumb ..	21,373	19,596	40,969
Blind	27,984	32,369	60,853
Leprous	9,240	4,607	13,847

The mean strength of **European soldiers** for 1878 was 10,528; admissions per 1,000 1,379·7; average daily number in hospital 65·8; deaths 22·1. The means of 19 years (1860 to 1878) are as follows:—admissions per 1,000 1,320; deaths per 1,000 19·13; invalided for discharge per 1,000 10·37; invalided for change of climate per 1,000 40·35. The means of sickness and mortality amongst the **women** of the European Army for 5 years (1869–1873) were—admissions per 1,000 1,003; deaths per 1,000

* Chiefly of hill-tribes whose deaths are not registered.

18·04. Amongst the **children** the corresponding numbers were 639 and 55·66.

The mean strength of **Native soldiers** serving in the Madras command during 1878 was 25,496; admissions 20,239. The means for eleven years (1868–1878) per 1,000 of strength are as follows:—admissions 781, daily sick 29·5, deaths 11·4.

The mean strength of **prisoners** in 1878 was 21,364, admissions to hospital were 944·4 per 1,000, deaths 125·4. The following are means per 1,000 for six years (1861-62-1866):—admissions 1,371, deaths 107·0; and for eleven years (1868–1878)—admissions 777·8, deaths 52·6.

Andamans.

Port Blair was garrisoned in 1878 by detachments of Europeans and N.I., the mean strengths of which were 130 and 584. Means per 1,000 for twelve years (1866–1877)—admissions 863·7, 1,497·0; daily sick 35·5, 53·2; deaths 11·0, 12·1.

A small detachment of Native troops was at one time stationed in the *Nicobars*. In 1873 the strength was 37, admissions were 268, daily sick 5, deaths 0. Means for four years (1869–1872)—admissions 6,017, daily sick 260, deaths 42·1.

Bellary.

The *District* comprises 11,007 square miles; inhabited, according to the census of 1871, by 1,668,006 persons, 152 to the square mile—occupying 316,693 dwellings. 5,853 are returned as houseless. The average of inhabitants to each house is 5·3. The numbers, distributed according to age and sex, were as follows;—boys under 12, 299,477; girls under 10, 255,059; adult males, 560,696; adult females, 552,774. The returns give 93·9 females to 100 males, a result obviously incorrect. Five municipal towns; Bellary (51,766), Adoni (22,723), Gooty (6,730), Anantapur (4,918).

The town of *Bellary* is garrisoned by European and Native troops. The strength of the former in 1878 was 869, the admissions were 1,607, daily sick 76·5, deaths 11. The means for twelve years (1866–1877) were—1,150·5, 62·2, 9·2. Of a strength of 98 women 164 were admitted, with 7 deaths; of 209 children, 225 admissions occurred and there were 16 deaths—76·5 per 1,000. The mean strength of Native troops was 1,642, with 1,600 admissions, 70·5 daily sick, and 40 deaths. The mean figures are 526·5, 22·8, and 9·4. In the District Jail the ratios per 1,000 for seven years, 1870–76, were—admissions 701·2, daily sick 26·0, deaths 20·2.

At the convalescent depôt of *Ramandroog* the average admissions in twelve years ending 1877 were 1,257·5 per 1,000, deaths 10·9.

Bengal.

Cuttack is garrisoned by a Native regiment; strength in 1878 658, admissions 566, daily sick 12·5, deaths 5. Twelve years' means per 1,000—672·5, 32·2, 8·2.

Burmah.

Moulmein is garrisoned by Native troops only; strength in 1878 361; admissions were 122, daily sick 5·1, with 6 deaths. Means of twelve years (1866–1877)—admissions per 1,000 1,069, daily sick 43·4, deaths 13·3.

Rangoon.—Mean strength of European troops 750, admissions 975, daily sick 39·1, deaths 20. Means of twelve years (1866–1877) 1,253·3, 55·9, 13·6. Of 85 women none died in 1878, and 13 children died out of 198, or 60·6 per 1,000. Mean strength of sepoys 1,441; admissions 997, daily sick 45·3, deaths 15. Means for twelve years—617, 29·6, 10·5.

Shoaygheen is garrisoned by a small detachment of N.I.; mean strength in 1878 115, admissions 219, daily sick 8·3, 1 death. Means for 1866-1877—admissions 1,993 per 1,000, daily sick 69·7, deaths 11·8.

Thayetmyo.—Strength of Europeans in 1878 618; admissions 761, daily sick 29·2, deaths 11. Means per 1,000 for 1866-1877—1,215, 46·2 20·8. Two deaths among 60 women in 1878 (33·3 per 1,000); of 112 children 8 died, (62·5 per 1,000). Strength of Native troops 601, admissions 538, daily sick 16·0, deaths 3. Means for 1866–1877—600, 25·8, 9·5.

Tonghoo.—Mean strength of European soldiers in 1878 398, admissions 430, daily sick 19·3, deaths 14. Means per 1,000 for 1866 1877—1,010, 49·5, 16·2. Of 40 women 1 died in 1878, 3 children died out of 63 (15·8 per 1,000). Strength of Native troops 701, admissions 746, daily sick 28·5, deaths 11. Means for the twelve years—969, 44·3, 15·8.

Central Provinces.

Chanda has a small Native garrison, the strength of which was 73 in 1878. There were 114 admissions, 3·2 daily sick, 1 death. Corresponding numbers per mille for 1866–1877—1,692, 46·4, 10·5.

Hoshungabad is occupied by a wing of N.I.; strength in 1878 363, admissions 539, daily sick 10·8, deaths 11. Means for the twelve years—924, 28·3, 11·6.

At *Kamptee*, in 1878, the mean strength of European soldiers was 845, with 1,245 admissions, 49·0 daily sick, and 16 deaths. Means for twelve years—1,670, 62·6, 16·1. Of a strength of 119 women in 1878, 170 were admitted and 4 (33·6 per 1,000) died; of 193 children 28 (145·0 per 1,000) died. The mean strength of Native troops was

1,315, giving 946 admissions, 30·6 daily sick and 17 deaths; the means for the twelve years' period being 807, 27·2, 9·9.

A N.I. regiment (strength in 1878 615) garrisons *Raepore*. There were 267 admissions, 10·8 daily sick, 3 deaths; the mean numbers being 958, 32·0, 12·1 per 1,000.

A detachment of the Kamptee European regiment is quartered at *Seetabuldee*. Its strength in 1878 was 18, giving 105 admissions, 1·9 daily sick and no death. A N.I. regiment is also quartered here: the mean admissions, daily sick and deaths in which, in the twelve years, were 1,448, 39·7, 7·1 per 1,000.

At *Seroncha* there is a N.I. detachment; strength in 1878 171, admissions 141, daily sick 6·9, deaths 3. Mean numbers 1,129, 45·9, 9·3.

A wing of a Native regiment is quartered at *Sumbulpore*, strength in 1878 306, admissions 301, daily sick 8·2, deaths 3. The twelve-yearly means per 1,000 were 1,204, 35·2, 11·2.

Chingleput.

The area of the *District* is 2,753 square miles; the population in 1871 returned as 938,184, having apparently increased 16·6 per cent. in the previous five years. The dwellings numbered 141,434, of which 7,376 (5·2 per cent.) were unoccupied. The average number of inhabitants was 7 to a house and 341 to a square mile. Of the population 475,968 were males, of whom 183,370 were under 10; and 462,216 females, of whom 165,662 were under 12. One municipal town; Conjeveram (37,327).

The district jail is at *Chingleput*. Means per 1,000, 1870-1876 admissions 1,509, daily sick 54·7, deaths 11·6.

Palaveram is the head-quarters of the European Artillery Veterans; but the following figures relate to detachments from European regiments quartered in Fort St. George, which go out for rifle practice, whose mean strength in 1878 was 126. The admissions were 9, daily sick 0·7, deaths 1. Native troops with a mean strength of 549 also were quartered here, giving 522 admissions, 30·2 daily sick, and 9 deaths. The N.I. Depôt which receives invalids from Burmah and other foreign stations is here. The means for twelve years (1866-1877) are 1,398, 114·7, 38·7.

Poonamallee is an Invalid Depôt for European troops, whose strength in 1878 was 159; admissions 237, daily sick 19·8 and deaths 11. The twelve years' means per 1,000 were 2,829, 231·0, and 58·9. Of 31 women none died, and of 72 children 3 died (41·6 per 1,000).

St. Thomas' Mount is the head-quarters of the Artillery, whose strength in 1878 was 313; admissions 371, daily sick 22·3 and deaths 5. The twelve years' means per 1,000 were 1,306, 63·8, 22·3 One death occurred among the women and the mortality of children was 83·3 per 1,000. A detachment of Native troops (strength in 1878 182) is also quartered here. Admissions were 85, daily sick 2·1, no deaths; and the twelve years' means—551, 20·6, 7·9 per 1,000.

Cochin.

Trichoor is occupied by a small detachment of N.I.; strength in 1878 165, admissions 71, daily sick 2·3, deaths 1. Twelve-yearly means per 1,000—445, 18·1, 63.

Coimbatore.

The *District* includes 7,432 square miles; population 1,763,274; houses 361,109, of which 16,446 were uninhabited; houseless persons 7,341; average of inmates in a dwelling 5·1, to a square mile 237. Population increased by 370,678 since 1866-67, 26·6 per cent. 101·5 females returned for 100 males. Of 874,975 males 338,298 were under 12; of 888,299 females 302,560 were under 10. Three municipal towns; Coimbatore (35,310), Erode (10,201), Karur (9,378). At the *station* of Coimbatore there are Central and District Jails. In the former, in 1878, admissions were 809, deaths 116·5 per 1,000. In the seven years (1870–1876) the means per 1,000 were—admissions 412, daily sick 19·0, deaths 28·3. In the District Jail for the same period, admissions to hospital per 1,000 were 1,293, daily sick 70·0, mortality 65·8.

Cuddapah.

The *District* comprises 8,367 square miles. Population in 1871 1,351,194 (161 to square mile); houses 339,063, of which 14,662 (4 per cent.) were unoccupied; average number of inmates, 5·3 in terraced, 4·4 in tiled, 4·0 in thatched houses, 85·2 per cent. of dwellings belonging to the last class. Increase of population since 1866-67 18 per cent. according to the returns. Females to males returned as 95 : 100. Of 693,400 males 237,325 were under 12; of 657,794 females 205,334 were under 10. One municipal town; Cuddapah (16,275). In the District Jail the means per 1,000 of 1870–1876 were—admissions 1,431, daily sick 38·5, deaths 41·4.

Ganjam.

The *District* covers 8,313 square miles, including much hilly and jungly country. Total population of the district proper 1,388,976; 1,520,088 if the inhabitants of the hill-villages scattered over 3,400 square miles are added. Mr. Cornish suggests the addition of 40,000 more to compensate the obvious under-estimate of the females in the hill-villages, who are returned as 47,295 to 83,817 males. The population would appear to have increased by 5 per cent. since the census of 1866. Females to males 99·8 to 100. Of the population of the district proper 508,326 were children; 276,389 boys under 12, 231,937 girls under 10; of the adults 418.906 were males and 461,744 females. Two municipal towns; Chicacole (15,587), Berhampore (21,670).

At *Berhampore* there was a Native wing and is a District Jail. The strength of the former in 1877 was 362; admissions were 230, daily sick 12·7, deaths 3. Means per 1,000 for eleven years (1866-

1876)—618, 26·7, 14·4. The means for prisoners in 1870–1876 were—admissions per 1,000 665, daily sick 28·9, mortality 47·0.

Godavari.

This *District* occupies 6,224 square miles, with a population in 1871 of 1,592,939—256 to the square mile. Houses 389,712, of which 20.339 were uninhabited, giving an average of 4·3 persons to a house. Since 1866-67 census the population appears to have increased by 11·5 per cent., the number of houses by 5·2. 94 per cent. of the houses are thatched. Of 1,025,818 adults 492,705 were males 533,113 females. Of the remainder 310,898 were boys under 12, 256,223 girls under 10: 98 females to 100 males, but 108 women to 100 men. Three municipal towns; Cocanada (17,839), Rajahmundry (19,738), Ellore (25,487).

In the Central Jail at *Rajahmundry* the means per 1,000 for seven years (1870-1876) were—admissions 794, daily sick 41·2, deaths 15·0. In the District Jail the corresponding numbers were—admissions 1,096, daily sick 45·3, deaths 31·9 per 1,000.

Hyderabad Territory.

The mean strength of the European force at *Secunderabad* (including Trimulgherry) in 1878 was 2,471; admissions 3,032, daily sick 174·8, deaths 62. The means per 1,000 for the previous twelve-yearly period were 1,259, 58·3, 24·7. Of 284 women 6 died (21·1 per 1,000). Of 539 children 64 died (115·0 per 1,000). The Native troops had an average strength of 3,158 with 2,595 admissions, 89·5 daily sick, and 52 deaths. The twelve-yearly means were 912, 34·1, 11·0.

Kistna.

This *District* covers 8,036 square miles, with a population of 1,452,374—181 to the mile. Of 282,358 houses 10,463 were uninhabited, and 3,407 persons were houseless when the census was taken. There were 5·3 persons to each inhabited dwelling. 82·7 per cent. of the houses were thatched, 9·3 tiled, and 6·9 terraced. The population appears to have increased by 12 per cent. since the census of 1866-67. Females are returned as 96·9 to 100 males. Of 737,495 males 271,008 were under 12, and of 714,879 females 233,490 were under 10. Two municipal towns; Masulipatam (36,188), Guntoor (18,033.)

In the jail at *Guntoor*, in the septennial period 1870–1876, admissions were 973, daily sick 35·0, and deaths 9 per 1,000.

The jail at *Masulipatam* gave admissions 1,000, daily sick 38·4 per 1,000, and no deaths.

Kurnool.

The *District* comprises 7,358 square miles, with a population in 1871 of 959,640—130 to a square mile and 4·9 to a house. Houses

205,881, of which 5 per cent. were uninhabited. Population appears to have increased 24·5 per cent. in five years. Females were to males as 95·5 to 100. Of 490,883 males 175,358 were boys, and of 468,757 females 148,269 were girls. One municipal town; Kurnool (25,579).

In the District Jail at *Kurnool* in the years 1870–1876 the means per 1,000 were—admissions 1,102, daily sick 33·9, and deaths 54·4.

Madras.

The City consists of 23 villages scattered over 27 square miles. The population in 1871 was 397,552—14,724 to the mile. Houses 51,741, with a general average of 7·6 inmates. Terraced houses had 9·7 occupants, tiled 8·2, thatched 4·3. Of 194,676 males 56,678 were under 12; of 202,876 females 47,211 were under 10.

The garrison included 590 Europeans and 2,093 Natives. The former gave 819 admissions, 58·7 daily sick, and 10 deaths in 1878; and corresponding means per 1,000 for twelve years (1866–1877) were 1,344, 71·7, and 20·2. One woman (12·3 per 1,000) and 9 children (52·3 per 1,000) died during 1878.

The admissions amongst the sepoys were 1,317 in 1878, daily sick 54·9, deaths 17; the corresponding twelve-yearly means being 665, 25·5 and 11·6.

In the Penitentiary in 1870–1876 the annual means per 1,000 were—admissions 827, daily sick 31·1, and deaths 13·7. In Her Majesty's Jail the numbers were 1,259, 24·0 and 0.

Madura.

The *District* extends over 9,502 square miles, and returned in 1871 a population of 2,266,615—239 to the mile. Houses 443,513, of which 3·5 per cent. were unoccupied, 1·6 per cent. were terraced, 4·5 tiled, 93·8 thatched. Average number of inmates 5·3. Increase of population in five years, according to returns, 16·5 per cent. 103·8 females to 100 males. Of 681,802 males 430,264 were boys; of 773,565 females 380,984 were under 10. Two municipal towns; Madura (51,987), Dindigul (12,865).

In the District Jail at *Madura*, in 1870–1876, the annual means per 1,000 were—admissions 418, daily sick 18·3, and deaths 45·7.

Malabar.

The *District* covers 6,002 square miles. Population 2,261,250—377 to a mile; and appears to have increased 21·8 per cent. in five years, owing partly to the extension of coffee-planting in the Wynaad. Houses 435,462, 13 per cent. unoccupied; average number of inmates 5·8. Almost all dwellings thatched. Females to males as 99 to 100 on the whole; but 101·7 to 100 if the population of the Wynaad, where men predominate, be excluded. 436,982 of 1,134,889 males were boys; 355,789 of 1,126,361 females were girls. Five

municipal towns; Tellicherry (20,504), Calicut (47,962), Palghat (30,752), Cochin (13,840), Cannanore (31,358).

At *Calicut* a company of the Cannanore European Regiment is stationed; its strength in 1878 was 98, admissions were 128, daily sick 6·1, and 3 deaths occurred. In the twelve years (1866–1877) the admissions were 1,306 per 1,000, daily sick 62·1, deaths 17·1. In the District Jail in 1870–1876 admissions were 780 per 1,000, daily sick 23·0, deaths 50·3.

The garrison of *Cannanore* averaged 640 Europeans and 896 Natives during 1878. Admissions from the former were 824, daily sick 34·2, deaths 13; the means per 1,000 for 1866–1877 being 1,150, 53·2, and 15·5. Of 98 women 1 died (10·2 per 1,000); of 229 children, 3 (13·1 per 1,000). The Native troops in 1878 gave 487 admissions, 18·7 daily sick, and 4 deaths; the twelve-yearly figures being 433, 17·4, 6·8. In the Central Jail in seven years (1870–1876) the means per 1,000 were—admissions 659, daily sick 32·2, deaths 36·0.

A European detachment is stationed at *Mallapooram*; strength in 1878 95, admissions 30, daily sick 1·7, deaths 2; duodecimal means 945, 40·6, 14·6.

Mysore and Coorg.

A force of 1,610 Europeans occupied *Bangalore* in 1878; admissions were 1,885, daily sick 105·5, deaths 17; the means per 1,000 for twelve years preceding being 1,163, 51·4, 12·3. Of 237 women 7 died (29·5 per 1,000); of 493 children, 24 (49·6 per 1,000). The average strength of Native soldiers was 1,768, with 998 admissions, 42·2 daily sick, and 22 deaths: the means per 1,000 for 1866–1877 being 751, 26·2, and 11·2.

A N.I. regiment is stationed at *French Rocks*; strength in 1878 570, admissions 668, daily sick 16·4, deaths 11. In the eleven years preceding the means per 1,000 were 696, 25·2, and 12·9.

There is also a Native regiment at *Mercara* in Coorg; strength in 1878 627, admissions 758, daily sick 25·3, deaths 14: means for previous duodecimal period 1,035, 40·0, 13·3.

A detachment from French Rocks is stationed at *Mysore*; strength in 1878 63, admissions per 1,000 for 1868–1877 733, daily sick 12·7, deaths 8·6.

Nilgiris.

The *District* was constituted in 1868. It includes 749 square miles with a population in 1871 of 49,501—66 to the mile. Houses 13,922, all occupied; 6·6 per cent. terraced, 5·2 tiled, 3·3 thatched. Inmates 3·6 to a house. Population appears to have increased by 11,359 since the census of 1866-67. Males 27,192, of whom 9,032 were under 12 Females 22,309 with 7,734 girls. Two municipal towns: Ootacamund (9,982), Coonoor (3,058).

At *Ootacamund* the Native Jail showed annual means per 1,000 in 1870–1876—528 admissions, 18·6 daily sick, and 24·8 deaths.

There is a Depôt for European Military invalids at *Wellington*

Average strength in 1878 407, admissions 427, daily sick 22·5, deaths 5. The means per 1,000 for the previous twelve years were 1,366, 78·5, 16·9. Of 83 women 2 died. Of 214 children 60·7 per 1,000 died.

Nellore.

The *District* occupies 8,462 square miles, with a population of 1,376,811 - 163 to the mile. Houses 263,820, of which 3·8 per cent. were empty and 93 per cent. thatched. 5·4 persons to a house. Increase of population since 1866-67 17·8 per cent. 94·6 females returned for 100 males. Of 707,392 males 248,362 were under 12; of 669,419 females 213,811 were under 10. Two municipal towns; Nellore (29,922), Ongole (7,392.)

In the District Jail at *Nellore*, in 1870–1876, mean annual admissions per 1,000 were 684, daily sick 22·3, deaths 20·4.

North Arcot.

The *District* extends over 7,139 square miles. Population 2,015,278 – 282 to the mile. Houses 329,844, of which 15,744 were unoccupied; inmates 6·1 to a house. Increase of population in five years 12·8 per cent. 97 females to 100 males. Of 1,020,678 males 385,495 were under 12; of 994,600 females 345,292 were under 10. Two municipal towns; Vellore (38,022), Walajapetta (12,103).

In the District Jail at *Chittoor*, in 1870–1876, mean admissions per 1,000 were 1,304, daily sick 44·0, deaths 30·4.

A N.I. regiment garrisons *Vellore*; strength in 1878 633, admissions 184, daily sick 9·2, deaths 14. Mean numbers for 12 years preceding 592, 25·7, 21·4. In the Central Jail the means per 1,000 for seven years ending 1876 were 626 admissions, 21·1 daily sick, 13·8 deaths.

Salem.

The *District* covers 7,483 square miles and contains a population of 1,966,995—263 to the mile, having increased 21·5 per cent. since the census of 1866-67. Houses numbered 391,519 with an average of 5 inmates to each. Females to 100 males 101·6. Of 975,502 males 382,087 were boys, and of 991,493 females 343,524 were under 10. One municipal town; Salem (50,012).

In the Central Jail at *Salem* the means per 1,000 for 1870–1876 were admissions 393, daily sick 15·8, deaths 18·0.

South Arcot.

The *District* extends over 4,873 square miles, and had in 1871 a population of 1,755,817, the French territory of Pondicherry not being included. Persons to a square mile 360; to a house 7·8. 228,761 houses, of which 2,979 were unoccupied. Population increased 39 per cent. in five years, according to the two censuses. 98·2 females to 100 males. 344,384 boys out of 835,922 males;

310,306 girls out of 869,895 females. Two municipal towns; Cuddalore (40,290), Chilambaram (15,519).

In the Jail at *Cuddalore* the annual means in 1870-1876 were admissions 79 per 1,000, daily sick 25·1, deaths 18·6.

South Canara.

The *District* includes 3,902 square miles with a population of 918,362—235 to the mile. 24,174 of the 184,569 houses were uninhabited and the average of inmates was 5·7. 1,754 persons were returned as houseless. All but 2,946 houses were thatched. The population appears to have increased 8·9 per cent. since the previous census. Females 99·8 to 100 males. Of 459,729 males 165,322 were under 12; and of 458,633 females 137,470 were under 10. One municipal town; Mangalore (29,712).

A N.I. regiment is stationed at *Mangalore*; strength in 1878 636, admissions 223, daily sick 10·0, deaths 5. Means per 1,000 for twelve years (1866–1877) 470 admissions, 17·5 daily sick, 9·1 deaths. In the District Jail the annual means in 1870–1876 were admissions 1,161 per 1,000, daily sick 43·6, deaths 48·3.

Tanjore.

The *District* occupies only 3,654 square miles, with a population of 1,973,731 or 540 to the square mile, showing an increase of 14 per cent. since the preceding census. Houses 369,984, of which 12,196 were unoccupied. Average number of inmates 5·5. Females 106·9 to 100 males. Male children 355,990 out of 953,968; females 317,259 out of 1,019,763. Five municipal towns; Tanjore (52,175). Kumbakónam (44,444), Máyavaram (21,165), Negapatam (48,525), Mannárgudi (17,703).

In the *Tanjore* District Jail in 1870-1876 the annual ratio per 1,000 were—admissions 596, daily sick 37·7, deaths 76·9.

Tinnevelly.

The *District* covers 5,176 square miles and returned in 1871 a population of 1,693,959 persons—327 to a square mile, which had increased by 11·3 per cent. in five years. Houses numbered 403,803, 93·5 per cent. thatched, 4·2 tiled, 2·1 terraced; 35,455 were unoccupied. Average number of inmates 14·6. 102·5 females to 100 males. Of 836,515 males 811,876 were boys; of 857,444 females 273,981 were under 10. Three municipal towns; Tinnevelly (21,044). Palamcottah (17,945), Tuticorin (10,565).

Palamcottah was garrisoned by a N.I. regiment; strength in 1878 563, admissions, 335, daily sick 13·6, deaths 9. Means per 1,000 for duodecimal period (1866-1877)—admissions 496, daily sick 18·2, deaths 8·2. In the District Jail in 1870-1876 annual admissions per 1,000 were 477, daily sick 17·2, deaths 38·5.

Travancore.

Quilon was occupied by a detachment of Native regiment. Strength in 1878 481, admissions 272, daily sick 15·4, deaths 6. Means per 1,000 for twelve years preceding, 484, 22·1 and 8·5.

Trichinopoly.

The *District* extends over 3,515 square miles, with a population of 1,200,408—341 to a mile. 210,690 houses, of which 4,683 were unoccupied, giving 5·8 persons to a house. An increase of population to the extent of 19·2 per cent. appears to have occurred since the census of 1866-67. 104 females to 100 males. Of 588,134 males 219,777 were under 12; of 612,274 females 197,754 were under 10. Two municipal towns; Trichinopoly (76,530), Srirangam (18,655).

Trichinopoly had a European and Native garrison. The mean strength of the former in 1878 was 269; admissions were 365, daily sick 17·9, deaths 14. The means per 1,000 for 1866-1877 were 1,348, 71·1, 17·9. 3 deaths occurred among 25 women. Of 40 children none died. The strength of Native troops was 1,872; admissions were 1,133, daily sick 42·2, deaths 18. The means for twelve years were 614, 19·1, and 11·2. In the Central Jail in 1870–1876, admissions per 1,000 were 360, daily sick 19·1, deaths 38·3. In the District Jail the corresponding figures were—admissions 710, daily sick 31·4, deaths 45·8.

Vizagapatam.

The *District* extends over 18,344 square miles, and had a population, in 1871, of 1,844,711—118 to the square mile. Of 428,181 houses, 90 2 per cent. were thatched; inmates 4·6 to a house. (Jeypore is not included in these figures; its population is 314,488 in 61,238 houses.) The increase of population in the district in five years had amounted to 11·6 per cent. Excluding Jeypore there were returned 96 females to 100 males. Adults were 104·6 per 100, children 82·7. Four municipal towns; Vizagapatam (32,191), Bimlipatam (8,744), Vizianagram (20,169), Anakapalle (13,044).

At *Vizagapatam* there are a European Veteran Company and a Native garrison. The strength of the former in 1878 was 56; admissions were 20, daily sick 0·9, deaths 6. The strength of Natives was 699; admissions were 453, daily sick 36·2, deaths 7. The means per 1,000 for previous duodecimal period were 710, 40·4, 11·6. In the District Jail in 1870–1876 admissions per 1,000 were 562, daily sick 24·4, deaths 65·0.

A regiment is quartered at *Vizianagram*; strength in 1878 566, admissions 371, daily sick 14·1, deaths 5. Means per 1,000 for 1866-1877 were 687, 31·9 and 11·2.

APPENDIX VI.

FAMINE FOODS.

THE following list* contains, in alphabetical order, the names of the principal wild plants eaten by the starving poor of Madras in time of famine :—

Botanical and Tamil Names.	Natural Order to which the Plant belongs.	Remarks.
1. Achyranthes aspera... *Na-yurivi.*	Amarantaceæ ...	Leaves eaten ; common everywhere on the plains.
2. Ægle marmelos ... *Vilva pazham.*	Rutaceæ ...	Fruit eaten.
3. Ærua lanata ... ... *Kun-pulay kirai.*	Amarantaceæ ...	Leaves eaten.
4. Æschynomene aspera. *Attunetti.*	Leguminosæ ...	Do. do. ; an aquatic plant.
5. Alternanthera sessilis. *Ponnanguni kirai.*	Amarantaceæ .	Leaves eaten.
6. Amarantus frumentaceus. *Poong kirai.*	Do. ..	Do. do.
7. Amarantus spinosus... *Mulluk kirai.*	Do. ...	Do. do.
8. Amblogyna polygonoides. *Siru kirai.*	Do. ...	Do. do.
9. Amorphophallus campanulatus. *Karunai.*	Araceæ ...	Large tuberous root eaten.
10. Aponogeton monostachyon. *Kotti kilangu.*	Juncaginaceæ ...	Roots eaten ; an aquatic plant.
11. Asystasia Coromandeliana. *Midehy kirai.*	Acanthaceæ ...	Leaves eaten ; common in hedges.
12. Azadirachta Indica ... *Veppam.*	Meliaceæ ...	The pulp between the skin and seed of the fruit is eaten.

* I am indebted to Surgeon-Major Bidie, M.B., for this list.

Botanical and Tamil Names.	Natural Order to which the Plant belongs.	Remarks.
13. Bambusa arundinacea. *Mungil Arisi.*	Gramineæ ..	The seed is eaten, but is apt to cause diarrhœa and dysentery.
14. Bassia longifolia ... *Illupai.*	Sapotaceæ ...	Flowers eaten; contain sugar.
15. Bassia latifolia ... *Kaat illupai.*	Do. ...	Do. do.
16. Blepharis mollugini-folia. *Kali-metan.*	Acanthaceæ ...	Eaten as greens.
17. Boerhavia diffusa ... *Mukaretti.*	Nyctaginaceæ ...	Leaves eaten.
18. Borassus flabelliformis *Panum pazham.*	Palmaceæ ...	Fruit and roots eaten.
19. Buettneria herbacea...	Sterculiaceæ ...	Leaves eaten.
20. Colocasia antiquorum. *Kuchu.* Colocasia Indica Do. nymphaeifolia.	Aroideæ ...	Leaves eaten, but they require to be cooked, being acrid in the raw state.
21. Canthium parviflorum. *Caray-chedi.*	Cinchonaceæ ...	Leaves eaten; they have astringent properties.
22. Caralluma ascendens. *Kulli mulaiyan.*	Asclepiadaceæ...	Young tetragonal stems eaten.
23. Cardiospermum hali-cacabum. *Mudacottan.*	Sapindaceæ ...	Young leaves eaten.
24. Carissa carandas ... *Kaluka.*	Apocyneæ ...	Fruit eaten.
25. Cassia fistula ... *Konraik-kay.*	Leguminosæ ...	Pulp of pods eaten; somewhat cathartic.
26. Cassia sophora ... *Periya-tagarai.*	Do. ..	Leaves said to be eaten, but purgative.
27 Chamissoa nodiflora... *Kamulli-kirai.*	Amarantaceæ ...	Leaves eaten.
28. Chenopodium *sp* ? *Chakra-vinthe-kirai.*	Chenopodiaceæ.	Eaten as greens.
29. Cissus quadrangularis *Perundai codi.*	Ampelideæ ...	Do. do.
30. Cleome viscosa ... *Nai velai.*	Capparideæ ...	Do. do.

Botanical and Tamil Names.	Natural Order to which the Plant belongs.	Remarks.
31. Comelyna Benghalensis. * C. Communis. *Kannang kirai.*	Commelynaceæ.	Leaves eaten as greens. Seeds eaten plain or prepared by heating, when they swell and are called *Pori*.
32. Cordia myxa ... *Peria-naruvili.*	Boraginaceæ ..	Fruit formerly known as Sebestens, and eaten as food in times of scarcity.
33. Corchorus olitorius... *Peratti kirai.*	Tiliaceæ ...	Plant and leaves eaten. It is the Jew's mallow or wild jute.
34. Cyperus rotundus ... *Koray kilangu.*	Cyperaceæ ...	The roots pounded are eaten.
35. Dipteracanthus prostratus. *Mookuthi kirai.*	Acanthaceæ ...	Leaves eaten as greens.
36. Eleusine Ægyptiaca . *Mathanga-pullu.*	Gramineæ ...	The seed, known as *Famine-corn*, is somewhat like raggi and is eaten by the poorer classes.
37. Erythroxylon monogynum. *Tevadarum.*	Erythroxyleæ ...	Leaves largely eaten in some districts during the famine. It is possible they may contain some principle like the famous "Coca," which the natives of Peru use as a masticatory to allay the pangs of hunger and prevent fatigue. "Coca" is the product of Erythroxylon coca.

Botanical and Tamil Names.	Natural Order to which the Plant belongs.	Remarks.
38. Euphorbia pilulifera. *Amampatchay arisi.*	Euphorbiaceæ ...	Leaves and shoots eaten as greens. Although it belongs to a dangerous family, seems quite safe.
39. Euphorbia thymifolia *Sittra-paladi.*	Do. ...	Leaves eaten.
40. Evolvulus alsinoides. *Vistnu krandi.*	Convolvulaceæ ..	Plant eaten as greens.
41. Ficus Bengalensis .. *Aala maram.* Ficus religiosa ... *Arasa maram.*	Urticaceæ ...	The fruit of various wild species of fig is eaten.
42. Gisekia pharnaceoides *Manal-kirai.*	Phytolaccaceæ. ...	Leaves eaten.
43. Guazuma tomentosa. *Thein puchi maram.*	Sterculiaceæ ..	Fruit eaten; an introduced tree.
44. Gynandropsis pentaphylla. *Velai.*	Capparideæ ...	Leaves eaten; have a pungent taste.
45. Inga dulcis ... .. *Korka-puli.*	Leguminosæ ..	Pods eaten.
46. Ipomœa reptans .. *Vellay-kirai.* Ipomœa sepiaria ... *Thali-kirai.*	Convolvulaceæ ..	Leaves eaten.
47. Leucas aspera .. *Thumbay-kirai.*	Labiatæ	Do. do.
48. Luffa tuberosa ... *Adolokay.*	Cucurbitaceæ ...	Fruit eaten.
49. Marsilea quadrifolia . *Aura-kirai.*	Marsileaceæ ...	An aquatic plant with shamrock like leaves which are eaten.
50. Mimusops elengi ... *Moghadum-pazham.*	Sapotaceæ ...	Flowers and fruit eaten.
51. Mollugo spergula ... *Thuroyelai.*	Caryophyllaceæ...	Leaves eaten.
52. Morinda citrifolia ... *Nona-kay.*	Rubiaceæ ...	Green fruit eaten.
53. Nymphœa lotus ... *Shungazhanir pushpum*	Nymphæaceæ ...	Seeds and roots eaten.

Botanical and Tamil Names.	Natural Order to which the Plant belongs.	Remarks.
54. Opuntia dillenii .. *Nagadali.*	Cactaceæ ..	Fruit and tender shoots eaten.
55. Orygia trianthemoides.	Mesembryaceæ	Eaten as greens.
56. Oxalis corniculata .. *Puliarai.*	Geraniaceæ ...	Do. do.
57. Pandanus odoratissimus. *Thazham.*	Pandanaceæ ...	Pulp of fruit eaten
58. Phaseolus trilobus ... *Nari-pythenkay.*	Leguminosæ ..	Leaves and seeds eaten.
59. Phœnix farinifera .. *Icham-kay.*	Palmaceæ ...	Fruit eaten.
60. Phœnix sylvestris ... *Pericham-kay.*	Do. ...	Do.
61. Portulaca oleracea ... *Covi-kirai.*	Portulacaceæ ...	Eaten as greens.
62. Portulaca quadrifida. *Passalai-kirai.*	Do. ...	Do.
63. Premna latifolia .	Verbenaceæ ...	Leaves eaten.
64. Prosopis spicigera .. *Parumbay.*	Leguminosæ ...	Mealy substance from the pods eaten.
65. Salicornia brachiata	Chenopodiaceæ...	Eaten as greens.
66. Salsola Indica ... *Pavala gundu.*	Do. ...	Do. do.
67. Schleichera trijuga ... *Pumarum.*	Sapindaceæ ...	Fruit eaten.
68. Schmidelia serrata .. *Tanalikay.*	Do. ..	Do. do.
69. Sida humilis ... .. *Valu pausi.*	Malvaceæ ...	Eaten as greens
70. Solanum Jacquini . *Cundung-katri.*	Solanaceæ ...	Fruit eaten.
71. Solanum torvum . *Sundak-kay.*	Do. ...	Do.
72. Spondias mangifera . *Murri-mangay.*	Anacardiaceæ	Do.
73. Sterculia fœtida ... *Pinari-kay.*	Sterculiaceæ ..	Seeds eaten.
74. Strychnos potatorum. *Teltan-cottay.*	Loganiaceæ .	Pulp of fruit eaten.

Botanical and Tamil Names.	Natural Order to which the Plant belongs.	Remarks.
75. Syzygium jambolanum. *Nagap-pazham.*	Myrtaceæ ...	Pulp of fruit eaten.
76. Tamarindus Indicus. *Puliyam-pazham.*	Leguminosæ ...	Fruit eaten.
77. Trianthoma decandra. *Vellai-sharunnai.*	Portulaceæ ...	Eaten as greens.
78. Trianthona obcordata. *Sharunnai.*	Do. ...	Do. do.
79. Vernonia cineria ...	Compositæ ...	Do. do.
80. Zizyphus jujuba ... *Elandap-pazham.*	Rhamnaceæ ...	Fruit eaten.

INDEX.

INDEX.

The numbers refer to paragraphs.

A.

B.

C.

The numbers refer to paragraphs.

D.

The numbers refer to paragraphs.

E.

F.

G.

The numbers refer to paragraphs.

H.

I.

K.

L.

The numbers refer to paragraphs.

The numbers refer to paragraphs.

The numbers refer to paragraphs.

T.

The numbers refer to paragraphs.

U.

V.

W.

Z.